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BULLETIN
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THE BULLETIN

of the

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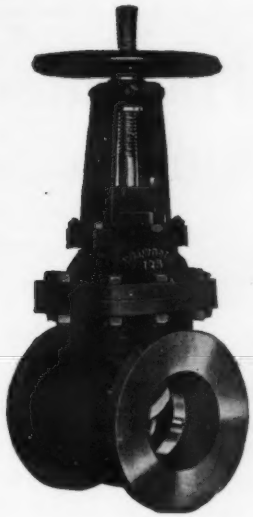

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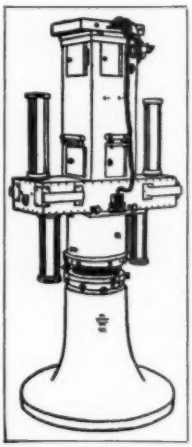

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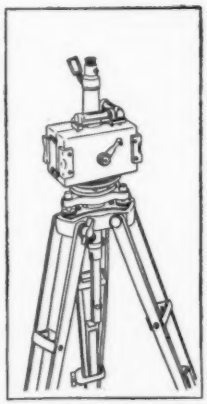

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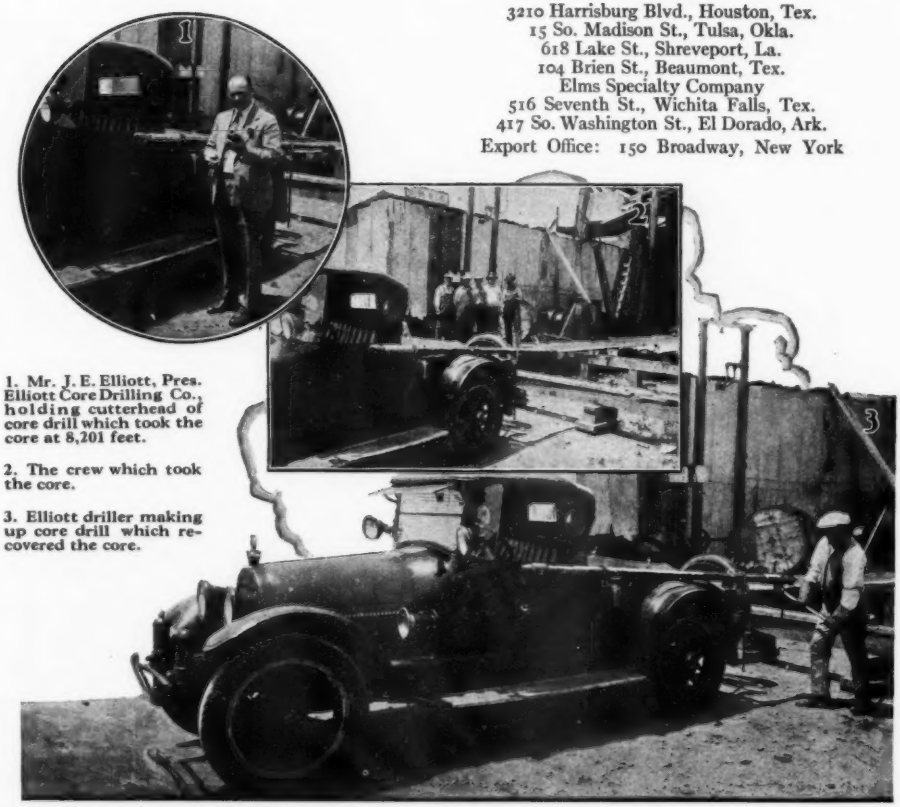

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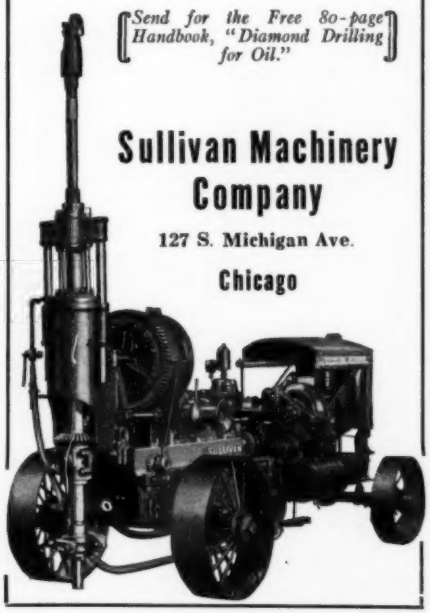

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Volume 12 Number 11

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NOVEMBER, 1928

COMPACTION AS A CAUSE OF THE MIGRATION OF PETROLEUM[1]

R. C. BECKSTROM[2] and F. M. VAN TUYL[3]
Golden, Colorado

ABSTRACT

The effect of generating CO_2 gas at the base of a charge of petroliferous sediments during compaction, using the apparatus designed for an earlier series of experiments, is described. Other tests with a cylinder of smaller bore in which much higher pressures were applied have indicated that a practically complete recovery of oil from a shale-water-oil mixture can be effected within a period of less than sixteen hours. The results warrant the conclusion that compaction is by far the most important cause of the migration of oil from shales into porous reservoirs.

INTRODUCTION

From our preliminary experiments, the results of which were published in October, 1926,[4] it was evident that compaction of water-wet sediments containing the higher grade crudes is an effective means of freeing the oil.

The apparatus employed in these experiments was constructed as follows:

A steel cylinder 11 inches high was prepared from a pipe with an inside diameter of 4 inches, the original diameter of which was reamed out to 4 ⅛ inches in order to give a uniform diameter and a smooth inner wall. One end

[1]Read before the Association at the San Francisco meeting, March 21, 1928. Manuscript received by the editor, September 1, 1928.

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[3]Professor and head of the department of geology, Colorado School of Mines.

[4]*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), pp. 917-30.

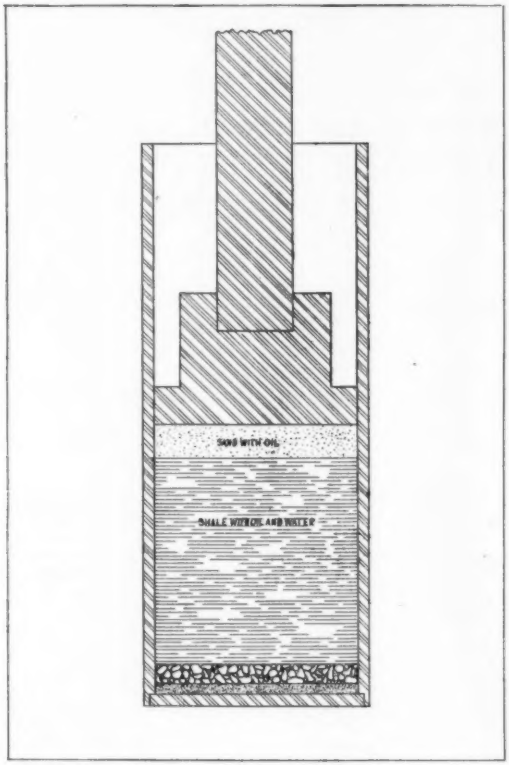

FIG. 1.—Diagram showing apparatus and charge employed to determine effect of evolution of gas during compaction.

was then closed by welding in a steel disk. A piston in the form of a heavy steel disk with a firmly attached piston rod 1½ inch in diameter was then turned down on the lathe exactly to fit the bore of the cylinder.

Several different charges of sediments containing oil and water were subjected to compression in the cylinder by means of a Riehle testing machine, the fluids being drawn off with a pipette from above the piston and measured. All of these tests were made at ordinary room temperatures.

The maximum recovery of oil obtained from the compacted shale in these preliminary tests was not more than 73.6 per cent at pressures

ranging up to 4,500 pounds per square inch throughout a period of 1½ hours.

The object of the new experiments was to determine (1) the effect of the generation of gas in the charge during compaction at slightly elevated temperatures and (2) the influence of higher pressures applied throughout a longer period of time on the yield of oil and water.

EFFECT OF THE EVOLUTION OF GAS AT ELEVATED TEMPERATURES

In order to determine the effect of the generation of gas at the base of the charge upon the recovery of the oil, the following experiment was undertaken. After placing an asbestos pad soaked in acetic acid in the bottom of the steel cylinder previously described, limestone fragments were introduced. A charge of oil-bearing shale prepared in the following manner was then added:

Powdered Benton shale	1,000 cc.
Water (mixed in first)	400 cc.
Oklahoma crude (30.5°API.)	300 cc.

Above the shale was spread 200 cubic centimeters of sand containing 50 cubic centimeters of oil, the object of this being to prevent the plastic shale from flowing upward around the edge of the piston (Fig. 1).

The apparatus was then placed in a water bath in order that the temperature might be regulated. Pressure was applied throughout a period of 7½ days.

The results during the first hour and a half are particularly interesting (Table I). During this period the pressure was raised by steps from 375 to 3,750 pounds per square inch, the average temperature of the bath being 45° C. and that of the fluids recovered from the cylinder 28° C.

The very high recovery of oil and the low yield of water during the early part of this period are ascribed to the influence of the rapid evolution of CO_2 gas as the acetic acid was driven from the asbestos pad. It is probable that CO_2 was not generated in large amounts in the later stages of the experiment.

At the end of the first day the apparatus was left in the machine at a pressure of 3,750 pounds per square inch. The next morning the pressure had fallen to 525 pounds per square inch. The temperature of the bath was 18° C. From this time on the pressure and temperature were raised at irregular intervals for 6 days, the pressure at first to 3,750 pounds but later to 4,500 and 4,875 pounds, and the temperature to about 45° C.

TABLE I

THE EFFECT OF COMPACTION OF SHALE WET WITH WATER AND OIL DURING THE EVOLUTION OF CO_2 GAS

Pressure on Charge	*Time at Various Pressures*	*Total Time Charge was Subjected to Pressure*	*Yield of Oil*	*Cumulative Yield of Oil*	*Yield of Water*	*Cumulative Yield of Water*
Pounds per Square Inch	*Minutes*	*Hrs. Mins.*	*Cubic Centimeters*	*Cubic Centimeters*	*Cubic Centimeters*	*Cubic Centimeters*
375	3	3	30.0	30	.5	.5
750	12	15	103.0	133	7.0	7.5
1,125	9	24	16.5	149.5	0.0	7.5
1,500	7	31	7.5	157.0	1.0	8.5
1,875	9	40	6.0	163.0	.5	9.0
2,250	7	47	4.0	167.0	1.0	10.0
2,625	12	59	4.0	171.0	.5	10.5
3,000	9	1 8	3.0	174.0	2.5	13.0
3,375	11	1 19	1.25	175.25	.75	13.75
3,750	11	1 30	1.5	176.75	1.00	14.75

In the afternoon of the second day the evolution of fluids had become so small that the apparatus was removed from the pressure machine and the charge examined. It was found that a thin, hard crust had formed at the top of the shale-water-oil mixture. A relatively soft mud was found below. After the crust had been punctured at several points pressure was again applied with a resultant increase in the fluids recovered. It is probable that no such condition would result in nature, inasmuch as the pressure built up in a sedimentary column increases with depth, thereby causing a decrease in compaction from below upward.

Upon the completion of the pressure tests the shale was again examined. It was found to be well compacted. A 3.3-gram sample of the shale from the bottom of the charge when treated with 10 cubic centimeters of carbon bisulphide gave only a faint coloration. The total recovery from this part of the shale was determined by colorimetric methods to be more

than 90 per cent as compared with a measured yield between 80 and 85 per cent for the entire charge. This difference is ascribed to the greater influence of the CO_2 gas on the lower part of the charge.

In this above described experiment, as well as those previously performed, no pressures above 4,875 pounds per square inch could be attained, owing to the large area of the cylinder. In order to determine the effect of much higher loads, similar charges of petroliferous sediments were compressed at room temperatures in a cylinder of much smaller bore designed by the junior author for the measurement of rock flowage pressures.

DESCRIPTION OF HIGH-PRESSURE APPARATUS

A section of cold-rolled shafting steel 3¼ inches in diameter and 3⅛ inches long was bored along the long axis with a ⅞-inch bit, the thickness of the wall being 1 $\frac{3}{16}$ inch. One end of the bore was then counterbored to a diameter of 1¼ inch for a distance of ⅞ inch and threaded. A bar of cold-rolled shafting steel 1¼ inch in diameter and 2⅛ inches long was threaded on one end to fit the cylinder, the other end being turned down to a diameter of 1⅛ inch. A cast iron collar with a diameter of 3¾ inches and a height of 1⅜ inch and with an opening sufficiently large to accommodate the head of the screw plug served as a base. The plunger was made from tool steel (Fig. 2).

HIGH-PRESSURE TESTS

A charge of oil-bearing shale was prepared as follows:

Benton shale (-100 mesh)	8.4 grams
Distilled water (mixed in first)	2.52 "
Texas crude (42.2° API.)	0.83 "

This was transferred to the cylinder and a fine wire screen placed above. A layer of dry disintegrated Dakota sandstone one inch thick was then added, the purpose of this being to absorb the water and oil given off under pressure and to prevent the shale from flowing upward around the piston. No attempt was made to measure the fluids involved, but determinations of the oil and water content of the compacted shale were made after the completion of the tests.

In the first experiment the pressures were raised gradually throughout a period of 50 minutes to a maximum of 100,000 pounds per square inch. The apparatus was then allowed to stand in the pressure machine for 15 hours. At the end of this time the pressure had fallen to 80,000 pounds. The screw plug in the base of the cylinder was then removed

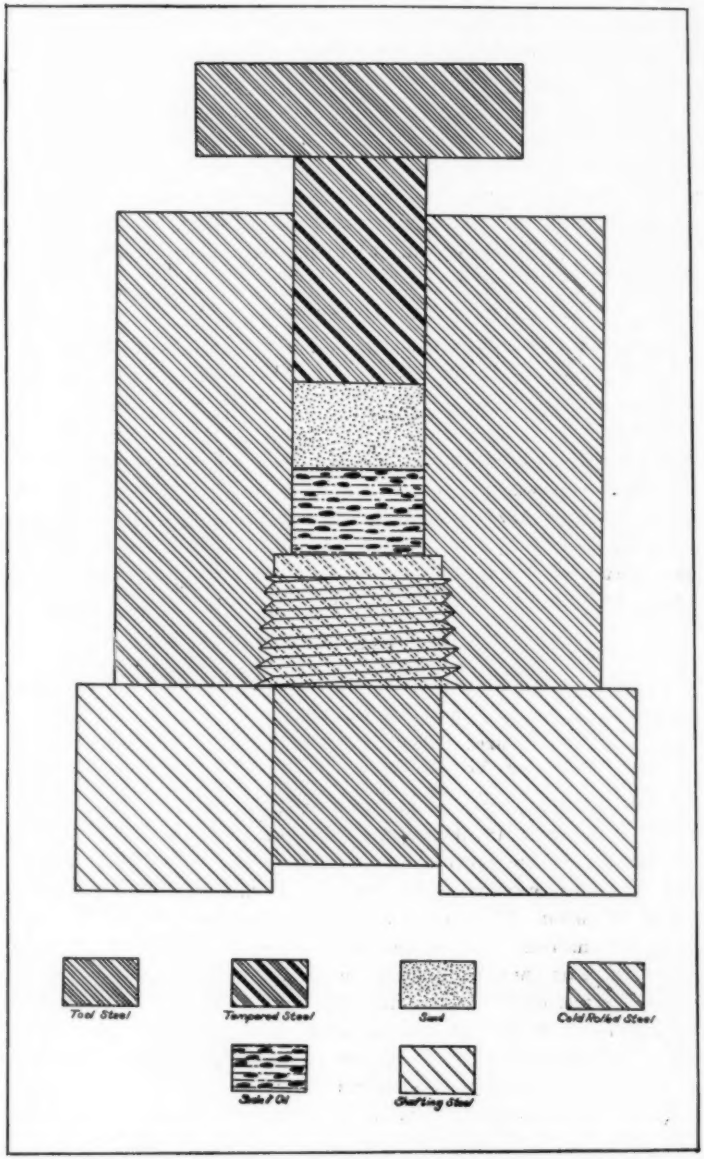

FIG. 2.—Diagram of apparatus employed in high-pressure compaction tests.

and the charge forced out by means of a chilled steel bar. The shale was found to be very hard and dense, while the sand was soft and moistened with water and oil.

The procedure in estimating the amount of oil left in the shale was as follows. A weighed amount of shale was treated with carbon tetrachloride, and the coloration, which was extremely faint, matched in a colorimeter with that of the same volume of this solvent, to which had been added a known amount of oil. The amount of oil left in the total shale charge was then calculated. The recovery of oil was found to have been 99.2 per cent, whereas that of water was 92.4 per cent. These results checked closely with the decrease in weight of the charge occasioned by the loss of fluids during compaction.

A similar test was made with a lower grade of Kansas crude under the same conditions and for the same period of time, the charge being as indicated below.

Benton shale (-100 mesh)	8.4 grams
Distilled water (mixed in first)	2.1 "
Kansas crude (28° API.)	0.658 "

The oil recovery was determined to be 99 per cent and the water recovery 92.7 per cent.

CONCLUSIONS

From a consideration of the results obtained in these experiments we favor even more than before the theory that compaction induced either by the weight of the overlying load or by dynamic action is an important cause of the migration of oil from shales into reservoir rocks. To be sure, the pressures employed in the last series of experiments are higher than those which would normally exist in a sedimentary column under static conditions, except where very thick accumulations have occurred, but it is probable that lower pressures operating throughout long periods of time would be equally effective. The generation of gas and the somewhat higher temperatures resulting from deep burial or structural adjustment undoubtedly promote the action.

THE POTENTIAL VALUE OF SEVERAL RECENT AMERICAN COASTAL AND INLAND DEPOSITS AS FUTURE SOURCE BEDS OF PETROLEUM[1]

PARKER D. TRASK[2]
La Jolla, California

ABSTRACT

Sediments obtained from several environments of deposition were assayed for their potentiality as future source beds of petroleum, by the method of dry destructive distillation. Except for deposits from an algal lake that yielded 28 gallons of oil a ton, the maximum production was about 3 gallons a ton. As is true with rocks of past geologic formations, recent sediments regarded as good potential source beds are not plentiful. The majority of modern deposits gave little or no oil on distillation and the samples from only four major regions, Lake Maracaibo, Pamlico Sound, and the limestone-forming areas of Florida and Cuba, produced more than 2 gallons a ton. In order to aid the evaluation of the potentiality of modern sediments as source beds, several deposits from past geologic formations were assayed in the same manner in which the recent sediments were treated. The results were strikingly similar to those from modern sediments, and support the view that the richer types of recent deposits are to be considered as potential future source beds. In general, the yield of oil from modern deposits increases as the texture becomes finer. This indicates that rocks formed from clay are more likely to be source beds than those made from silt or sand. The relatively high yield from the limy oozes of Florida and Cuba indicates that limestones may be mother rocks of oil. Deposits subject to considerable tidal action do not appear to be good future source beds. A suggestion is made that the organic content of sediments deposited relatively near shore is likely to be richer than that of those laid down far from land. If this is true it supplements other evidence pointing to the importance of shore-line conditions in the formation of oil. However, locally, the distribution of organic matter in sediments is influenced by the action of waves and currents, which may cause differences in the potentiality of sediments as source beds, even though the physical characters of the deposits may seem to be similar.

INTRODUCTION

This paper is a progress report based on the second year's work on American Petroleum Institute Research Project No. 4. The object of this investigation is to study the conditions under which sediments that may be future source beds of petroleum, are accumulating to-day. An account

[1]This paper contains preliminary results of an investigation on the "Origin and Environment of Source Sediments," listed as Project 4 of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by John D. Rockefeller. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council. Manuscript received by the editor, September 4, 1928.

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of the first year's work was presented in this *Bulletin* last November.[1] At the time of writing that paper, a reconnaissance of the organic content of sediments in different environments of deposition in American coastal waters was being made with the object of ascertaining, if possible, what kinds of present-day deposits could be regarded as potential future source beds of petroleum, and in what areas the richer deposits of this type were accumulating, so that later those regions could be studied in detail. The work of the past year has been completing the collection of sediments for this reconnaissance and analyzing, in the laboratory, representative specimens from each environment. The index of the potentiality of a sediment as a future source bed was determined, as was done previously, by distillation of the sample in the same manner in which oil shale is assayed.

The amount of oil produced on distillation may not be an index of the potentiality of a sediment as a future source of petroleum, but no more suitable method of determining this potentiality was called to the attention of those connected with the project. Although many of the sediments produced oil on distillation, it is not to be inferred that the writer maintains that oil is formed by a similar process in the ground. Some samples give no oil on distillation, but that does not mean that those sediments contain no organic matter, but only that they are probably not such good potential future source beds of oil as some of the deposits that yield more oil on distillation; therefore, presumably they are to be considered as relatively poor in organic matter.

Since the distillation of representative samples from the different environments of deposition from which sediments were obtained has not been completed, and many supplementary data remain to be determined, this report is only a summary of the more important features brought out in the work thus far.

The writer wishes to express his appreciation of the aid received from the advisory committee in charge of the work. This committee was composed of W. A. J. M. van Waterschoot van der Gracht, chairman, Austin H. Clark, and T. Wayland Vaughan. Acknowledgment is due The Scripps Institution of Oceanography of the University of California for laboratory and oceanographic facilities connected with the work. In a summary report like this the writer regrets that space does not permit the proper recognition of many people and organizations that have coöperated generously in the work. However, special mention

[1] P. D. Trask, "Results of Distillation and Other Studies of the Organic Nature of Some Modern Sediments," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 1221-30.

should be made of the assistance received from the U. S. Coast and Geodetic Survey, the Gulf (Oil) Companies, and various subsidiaries of the Royal Dutch Shell Company.

GENERAL PROCEDURE OF WORK

Regions from which samples were obtained.—As the main object of the reconnaissance was to ascertain the general distribution of source material in recent coastal sediments, samples were procured from as many different environments of deposition as possible, and each region was sampled as representatively as was practicable. As the mother rocks of petroleum of most of the present oil fields are generally believed to be marine in origin, attention was concentrated on marine deposits. Samples were procured from more than 500 localities in the following environments of deposition: the Bay of Fundy, a region of strong tidal action in which red sediments are being re-deposited without material change of color; the Gulf of Maine, a small epi-continental sea located in a temperate climate and having a very uneven floor; Great South Bay, a long, narrow lagoon on the south side of Long Island, New York; the Potomac estuary; Pamlico Sound, a body of shallow brackish water bordering the extensive swamps of eastern North Carolina; Mud Lake, an algal, alkaline lake located approximately 20 miles northeast of Ocala in northern Florida; lagoons and bays on the east and west coasts of Florida; limestone-forming regions of Florida Bay and the Gulf of Batabanó, Cuba; lagoons and bays of southern Texas, of which Baffin Bay represents, in a semiarid climate, a concentration basin that has a restricted connection with the sea; the Gulf of Venezuela, a small tropical epi-continental sea in an arid environment; Lake Maricaibo, a large tropical brackish-water lagoon having a maximum depth of about 30 meters; several small bodies of water associated with the Gulf of Venezuela and Lake Maracaibo, of which Laguna Sinamaica, a small circular, shallow lagoon, having a restricted connection with the north end of the Maracaibo channel, is most significant; the continental platform on the northeast coast of Venezuela near Carúpano; the Orinoco delta, the deposits of which represent conditions practically unaffected by man, in contrast with the present abnormal deposits of the Mississippi delta; the Colorado delta at the head of the Gulf of California; San Diego, Newport, and San Francisco bays, California; the Channel Islands region of southern California, an area of considerable submarine relief in which diastrophism is probably now occurring; the continental platform and Gray's Harbor on the coast of Washington, where epidemics

of diatoms occur; Puget Sound and Georgia Strait; Great Salt Lake; and a playa lake near Yermo, California. Unfortunately no samples were procured from such important areas as the Gulf of Mexico, the Mississippi delta, parts of the Gulf of California beyond immediate influence of the Colorado delta, Bering Sea, the Arctic Ocean, and Hudson Bay; but the obtaining of sediments from these regions is in prospect. Samples are in prospect also from the Malayan archipelago, especially the Moluccan seas, a region in which diastrophism is believed to be as active now as anywhere on earth.

Manner of analysis.—As soon as the sediments were brought to the laboratory they were dried on a sand bath at less than 100° C. This was done primarily to inhibit bacterial decomposition. As drying caused most samples to cake, it was necessary to pulverize them before proceeding further. Following pulverization, the sediments were classified macroscopically as to texture and then analyzed for ignition loss. The calcium carbonate content of several samples was determined, so as to aid the evaluation of the ignition test.

The data thus obtained facilitated the selection of sediments to be distilled. As the distillation test involved considerable time and required a relatively large amount of material, only a few samples from each environment could be distilled. However, in so far as was practicable, sufficient samples to check results were distilled from each environment. Eighty-seven distillations[1] of recent sediments were made.

The manner of distillation is the common method of assaying oil shale,[2] which was used on the Pamlico sediments.[3] However, a few modifications were effected. An electric furnace was used in place of gas as a heating unit, thus making it easier to control the temperature; the gas formed during distillation was collected in a gallon jar and at the end of the experiment was tested for its inflammability; and a small glass T-tube having appropriate attachments was used to connect the distal end of the iron outlet of the retort with the glass condensing tube and the graduate in which the distillate was collected. This glass T-tube has an advantage over the iron tee recommended by Karrick in that it facilitates ascertaining whether small quantities of oil are forming. The specific gravity of the oil was determined by immersing small drops in mixtures of ethyl alcohol and water of known density. The specific gravity of the alcohol-water mixtures was determined at 60° F. by means

[1]This total does not include the 45 distillations made during the first year.

[2]L. C. Karrick, "Manual of Testing Methods for Oil Shale and Shale Oil," *U. S. Bureau of Mines Bull. 249* (1926), pp. 6 *et seq.*

[3]P. D. Trask, *op. cit.*, p. 1223.

of a hydrometer, and the determinations of the density of the oil, though crude, represent a fair approximation to the true value. Such small amounts of oil were produced that it was not practicable to use a pycnometer, except on one sample, which gave the same value as was obtained from the alcohol-water mixture.

The sediments were dried at 105° C. before distilling. As the distillate was collected in 50-milliliter flasks, the yield could not be estimated closer than to 0.1 milliliter. Consequently, since each milliliter represented approximately 1 gallon per ton, the expression of the yield in gallons per ton throughout the paper is accurate approximately only to the first decimal place.

RESULTS OF DISTILLATION

General remarks.—The products of distillation were similar to those from the Pamlico sediments, except that in general the yield of oil was much less. As a rule, similar deposits from individual environments of deposition duplicated results fairly closely, especially with respect to the quantity and specific gravity of the oil formed, thus giving confidence in the reliability of the method. However, considerable difference in the products of distillation was noticed in different environments.

Except for the algal deposits from northern Florida, that produced 28 gallons a ton, the maximum yield of oil was about 3 gallons a ton. This is slightly more than 1 per cent of the weight of the sample. Several gallons of amber or lemon-colored watery fluid were produced per ton, and in several tests a black substance, similar to that prevalent in the distillates from the Pamlico sediments, gathered in the lower portion of the watery fluid. This black substance, as a rule, did not begin to form until a temperature of 550° C. was reached, and the quantity produced, on the whole, was very much less than from the Pamlico sediments. More than 25 per cent of the samples did not produce any of this black substance and almost the same proportion gave only a trace.

The residue in the retort after distillation was generally black or dark gray in color, except in sediments that yielded little or no oil. In these it was only slightly darker than in the original sample. The ignition loss of this residue left after distillation varied somewhat, but the average was about 25 per cent of the ignition loss of the original sample.

Oil yield.—The sediments of four relatively large environments of deposition produced more than 2 gallons of oil per ton. These regions are the central, deep part of Lake Maracaibo, the limestone-forming areas of Florida Bay and the Gulf of Batabanó, and Pamlico Sound. Sediments from Anticostia Creek in Washington, D. C., and the harbor

at Cardenas, on the north side of Cuba, gave more than 2.5 gallons a ton, but it is possible that these samples were contaminated with sewage. The deposits from Great South Bay, New York, Laguna Sinamaica in Venezuela, and the bottom of a depression in the Gulf of Maine near Georges Bank produced approximately 1.5 gallons per ton. Those from the Channel Islands region of southern California formed up to 1.3 gallons a ton from samples that had been extracted previously with ether. The sediments from Carúpano, Venezuela, gave about a gallon a ton, and one sample from Nueces Bay, Texas, and one from Puget Sound yielded 0.5 gallon. All other deposits gave practically no oil, and several did not even produce a trace.

The regions having sediments which yielded little or no oil include the Bay of Fundy; the Gulf of Maine, except the bottom of the depression near Georges Bank; the Potomac estuary; lagoons and bays of the east and west coasts of Florida; limestone-forming sediments from the vicinity of Key West; bays and lagoons of south Texas; the Gulf of Venezuela and associated bodies of water; shallow and near-shore parts of Lake Maracaibo; the Orinoco delta; bays of California; Gray's Harbor and the continental platform on the coast of Washington; Georgia Strait; Great Salt Lake; and the playa lake near Yermo, California.

Of special interest is the insignificant yield of oil from the samples from the outer Florida Keys in contrast with the relatively large production from similar deposits nearer the mainland. Similarly, sediments from the bottom of two depressions in the Gulf of Maine, located considerably nearer shore than the depression the deposits of which produced 1.5 gallons per ton, yielded practically no oil at all. Silt-like samples from near Goat Island in San Francisco Bay, taken in 23 meters of water and from depths of 9, 35, and 53 meters beneath the surface of the deposits, yielded less than 0.1 gallon per ton.

Types of oil produced.—Several types of oil seem to have been formed, as the color and specific gravity of the oil were not the same in samples from different environments of deposition. However, as a rule, the oil from any one particular region was similar in color and density throughout that area. The oil from the samples from the middle of Lake Maracaibo was light brown and had a specific gravity of .885, or 28.4° Bé. Those from the limestone-forming regions of Florida and Cuba were dark brown and about .915, or 23° Bé., in density, and those from the Pacific coast were very dark brown and approximately .940, or 19° Bé. Two samples of the algal deposits from Florida were distilled, one at the normal rate of heating and the other at a more rapid

rate. The quantity of oil was the same in both tests, but the specific gravity differed considerably, being .925 in the first and .980 in the second.

It was characteristic of the oil from all the samples to increase in density with time, the increase in a few months generally ranging from .010 to .030. This suggests that the oil contained unsaturated compounds.

Temperature of formation of the oil.—The range in temperature of formation of the oil was similar to that from oil shale and the Pamlico sediments. In general it ranged from 350° to 550° C. The temperature at which the first oil was observed varied considerably and evidently was dependent upon the oil yield, as the less the amount of oil formed the higher the temperature at which it began to form. This was also the experience with the Pamlico sediments, but when the results from those deposits were first interpreted, the temperature of initial oil formation was correlated with the texture, as sands produced the first oil at about 490° C., silts at 400° , and clays at 375°.

Gas.—Gas was produced at all temperatures up to 900° C., which was the highest temperature attained in any distillation. However, in general, it was not practicable to carry the temperature beyond 700°, and all determinations of gas production are on the basis of the yield up to 700° C. The amount of gas formed and the readiness with which it would burn varied roughly with the oil yield. The average yield from samples that produced less than 0.1 gallon per ton was about 8 milliliters of gas per gram of sediment, or approximately 250 cubic feet per ton. The average yield from those that formed more than one gallon of oil per ton was more than 20 milliliters of gas per gram, or 640 cubic feet per ton. A yield of 125 milliliters per gram or 4,000 cubic feet per ton was obtained from the algal deposits in Florida. However, some individual samples deviated considerably from these averages. This was especially true of carbonate-rich sediments, which generally produced more than carbonate-poor sediments.

The rate of production of gas commonly increased at a temperature of about 550° C. In carbonate-rich sediments, this might be explained by the decomposition of carbonates, but as it was noticed from sediments containing little or no carbonate and in some samples was associated with an increase in degree of inflammability of the gas, it evidently is due in part to other causes. It is possible that the increase in gas production at 550° may be associated with the cessation of oil formation, which occurs at about that temperature.

As a rule, gas from sediments of all types, including sands and most deposits yielding little or no oil, would burn. The color of the flame was ordinarily pale blue, but in samples that burned very readily it was commonly white or bluish-white. The gas from several sediments did not burn. These included silts from Nueces, Corpus Christi, and Baffin bays in Texas, a sand from Laguna Madre, a limy ooze from near Key West, silts and clays from the Gulf of Venezuela, a clay from a tidal marsh in San Francisco Bay, silts from depths of 9 and 35 meters beneath the surface of the bottom deposits in San Francisco Bay near Goat Island, sands from the vicinity of Gray's Harbor in Washington, an oölite from Great Salt Lake, and a playa silt from southeastern California. However, the gas from deposits in the regions mentioned is not to be considered as totally uninflammable, as some samples from most of the regions did produce inflammable gas, which could generally be burned with great difficulty.

Ignition loss.—Previous studies of sediments from Pamlico Sound and the Channel Islands region of California indicated that in those regions individual ignition tests were fairly good indices of the organic content.[1] However, this relation has not proved to be a general law, because in sediments investigated subsequently, considerable variation in oil yield has been observed from samples having the same ignition loss. For example, the range in oil production from carbonate-poor sediments having 10 per cent ignition loss was from 0 to 2.7 gallons per ton. However, the average ignition loss of all types of sediment from all regions varies directly with the oil yield.

INTERPRETATION OF RESULTS

As considerable work remains to be done on essential phases of the problem, only a preliminary discussion of the inferences to be derived from the work can be presented in this paper.

Evaluation of potentiality of deposits as future source beds.—Since the distillation test in the beginning was assumed to be a measure of the potential value of recent sediments as future source beds, it is desirable to evaluate that assumption. A yield of about 2.7 gallons a ton means that 1 per cent of the total weight of the sediment can be made to volatilize and condense to a liquid oil. Considerable gas is formed during distillation, which in part represents additional organic matter that might be available for the production of oil under geologic conditions. It is difficult to estimate how much of the organic content as determined by the method of distillation, if any, would be available for oil production

[1] *Loc. cit.*, p. 1228.

in the ground; particularly since at present it is not known what proportion of the organic matter in sediments at time of deposition resists decomposition and ultimately becomes preserved after the deposits have been lithified. However, for the purpose of comparison, let us assume that 0.5 gallon of oil would be formed per ton of rock. This is only one-sixth the production of some of the recent sediments and seems a conservative estimate. Then if a source bed 300 feet thick be assumed, with a specific gravity of 2.25, approximately 7,000,000 barrels of oil would be produced per square mile, or to put it another way, approximately 23,000 barrels of oil per foot of thickness of source bed per square mile.[1] This would be sufficient to meet the requirements of a fair-sized oil field. This line of reasoning, although based on the unproved assumption that 0.5 gallon of oil would be formed per ton, suggests that the richer types of recent deposits are to be regarded as potential future source beds of oil.

Comparison with yields from past geologic formations.—The evaluation of the potential future source-bed value of recent sediments was approached from another angle. Through the coöperation of other geologists, several samples from the Paleozoic of Texas and Oklahoma, the Cretaceous of Texas and California, and the Tertiary of Texas, Venezuela, and California were sent the writer. These sediments were taken largely from well cores and were regarded favorably as source beds of oil by those who collected them. They represent a rather wide stratigraphic and geographic distribution. Thirty samples were distilled in the same manner in which the recent deposits were treated. The similarity of results is very striking. Eighteen samples produced practically no oil, ten yielded between 1 and 3 gallons a ton, one from the Eagle Ford, 4 gallons, and one from the Monterey, 6 gallons. The average ignition loss varied directly with the oil yield and was very similar to that from recent sediments. Furthermore the specific gravity of the oil, the temperature of formation of the oil, the gas production, and the average ignition loss of the coke, were all similar to the results from recent deposits. In regard to past geologic sediments, it is unknown how much oil has migrated in or out of the deposits; but the striking similarity of the results from such a wide variety of past geologic sediments to corresponding results from recent deposits, supports the view that the better grades of sediments forming to-day are to be considered

[1] A source bed 300 feet thick means that there would be 309,760,000 cubic yards per square mile. A specific gravity of 2.25 means that the rock would weigh $27 \times 62.43 \times 2.25$ pounds, or about 1.9 ton per cubic yard. The weight of source beds per square mile would therefore be about 588,000,000 tons, which, according to the assumption of 0.5 gallon per ton, would produce 294,000,000 gallons, or 7,000,000 barrels, for a 300-foot thickness of source bed and 23,333 barrels for one foot of source bed.

as potential future source beds, although perhaps not so good as some past geologic deposits.

Relation of texture to oil yield.—As was true in the Pamlico and Channel Islands sediments, the organic content, as measured by distillation, in general varied directly with the texture. Half the samples classified as clay by macroscopical inspection produced more than 1 gallon of oil per ton, compared with only 8 per cent of the silts. Similarly, only four out of eighteen sand samples produced a measurable quantity of oil, and the maximum yield was 0.2 gallon a ton. However, there was considerable variation in relation of oil yield to texture, as one-fourth the samples classified as clay and nearly one-half the silts yielded less than 0.1 gallon a ton.

Types of sediment regarded as source beds.—From these data it follows that clays are more likely to be source beds than either silts or sands. The limestone-forming sediments of Florida Bay and the Gulf of Batabanó produced as much oil as did any of the marine sediments. Consequently they are to be considered as good source beds as any of the clays or silts.[1] However, limestone-forming deposits from the outer keys near Key West, located a considerable distance from the mainland, gave less than 0.1 gallon per ton and are not to be regarded as source beds. Therefore, it can not be inferred that limestones in general are potential source beds of oil, but only that some of them may be.

Deposits that are subject to considerable tidal action do not seem to be good potential source beds. However, at this stage of the work, since tidal deposits have not been studied in detail, it is not known whether the few examples now available are indicative of tidal deposits in general; but sediments from Gray's Harbor, the tidal flats and shallow portions of the south end of San Francisco Bay, San Diego Bay, the Bay of Fundy, and the Orinoco delta,—all regions of considerable tidal action—yielded an insignificant amount of oil, the maximum from any of these areas being 0.2 gallon a ton. Naturally, many of these tidal deposits are relatively coarse-grained in nature, but those from the Orinoco delta and San Francisco Bay are silt-like or clay-like in texture.

As algæ are generally regarded as being associated with the formation of oil shale,[1] the yield of 28 gallons a ton from the algal lake in Florida is significant.

[1]P. D. Trask, "Limestones as a Source of Oil," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1928), pp. 556-57.

[1]David White, chapter on organic sediments, in *Treatise on Sedimentation*, by W. H. Twenhofel, Williams and Wilkins Company, Baltimore (1926), pp. 289-304.

W. H. Bradley, "A Contribution to the Origin of the Green River Formation and its Oil Shale," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9 (1925), pp. 247-62.

General relation of plankton to organic content.—As plankton is the ultimate source of most life in the sea, its distribution and quantity must have an important effect on the organic content of marine sediments. Although much of the plankton is devoured by other forms of life, a significant proportion of it probably finds its way into the bottom deposits, thus presumably becoming an important source of organic matter in sediments. On the whole, plankton is much more plentiful near shore than it is in the open sea.[1] Thus it seems that sediments deposited relatively near shore are likely to be richer in organic matter than those laid down far from land. If this is true it supplements other evidence pointing to the importance of shore-line conditions in the formation of oil. Unfortunately it was not possible to test this hypothesis satisfactorily, but the low yield of oil from the limy oozes near Key West, compared with the high production near shore, would be explained by it.

However, where the continental platform extends a considerable distance from shore, as off the coast of Newfoundland, plankton may be plentiful. Consequently it is possible that this hypothesis of low organic content far from shore may not be true for deposits of epicontinental seas.

Local relation of plankton to organic content.—A large quantity of plankton in surface waters does not necessarily imply a high organic content in the sediments below. Since plankton has nearly the buoyancy of sea water, it does not need much current to move it as it is falling toward, or after it has come to rest upon, the sea bottom. Therefore, if the sea bottom is washed by currents or stirred by wave action, plankton particles are likely to be moved along until they reach a place in which they are unaffected by currents or from which they can not be washed out. Because of difference in buoyancy, plankton particles could be transported by considerably weaker currents than are needed to move clay or silt particles of the same size. Thus, even though the rain of plankton might be fairly uniform over a wide area, if depressions existed in the sea floor in that region it seems probable that organic matter derived from plankton might be concentrated in those depressions.

Such a hypothesis would account for the concentration of organic matter in the depressions in the Channel Islands region.[2] Similarly, in Lake Maracaibo the oil yield from sediments from the shallower parts

[1]H. H. Gran, Chapter VI in *The Depths of the Ocean*, by J. Murray and J. Hjort, Macmillan and Company, Ltd., London (1912), p. 366.

[2]P. D. Trask, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), p. 1229.

is much less than it is from the deposits from the deep, central part of the lake. The hypothesis affords also an explanation of the relatively low organic content of the sediments on the continental platform on the coast of Washington. Although the surface water in this region is known to be rich in diatoms during certain parts of the year, samples of sandy silt, taken near the edge of the continental platform in water 110 meters deep and more than 25 miles from shore, produced only 0.1 gallon of oil per ton. Evidently the severe storms that occur in this region tend to agitate the ocean bottom, thus inhibiting the accumulation of plankton, and causing it to be deposited in some other place, presumably in the abyssal deeps beyond the continental platform.

CONCLUSIONS

1. As a result of the study of several different environments of deposition of sediments, it seems that some deposits that may be potential future source beds of petroleum are accumulating to-day; but such deposits do not seem to be plentiful.

2. In general, the potentiality of a sediment as a source bed increases as the texture becomes more fine-grained.

3. Some limestones are to be regarded as potential source beds.

4. Deposits subject to considerable tidal action, according to present information, are evidently poor potential source beds.

5. The distribution of organic matter in sediments is, among other things, a function of the waves and currents; therefore, in an environment of deposition, organic matter may be concentrated in sediments of certain areas and impoverished in others. Thus, differences in the potentiality of the deposits as source beds may occur, even though the physical character of the sediments may seem to be similar.

FUTURE PLANS

Now that the work has advanced thus far, it is planned to study in detail a few regions in which the better potential source beds are now accumulating. The sediments in these areas are to be investigated with respect to (1) the environmental conditions under which they are being deposited; (2) the constituent parts that compose them; and (3) the changes that may be produced in them during or after deposition by different physical, chemical, or biological agencies. As a result of such investigations, it is hoped that the problem of the origin of oil will be nearer solution and that criteria will be developed that will aid the geologist in recognizing source beds in his geologic prospecting for oil.

A PRELIMINARY STUDY OF THE TRINITY GROUP IN SOUTHWESTERN ARKANSAS, SOUTHEASTERN OKLAHOMA, AND NORTHERN TEXAS[1]

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ABSTRACT

The stratigraphic relations of the formations of the Trinity group (Lower Cretaceous), at the outcrops in southwestern Arkansas, southeastern Oklahoma, and northern Texas are described briefly and represented graphically by cross sections and a correlation diagram. A new unit in the Arkansas section, the Holly Creek, is defined. Another unit, the Paluxy, is recognized and shown to be continuous across southeastern Oklahoma into the typical Paluxy of northern Texas. The Dierks-DeQueen interval of Arkansas-Oklahoma is correlated, first with the Glen Rose of northern Texas, then with the upper Glen Rose of northwestern Louisiana, on the basis of stratigraphic position and fossils. Two units of the Trinity group in the northwestern Louisiana section, not heretofore described, are briefly mentioned. The one is a thick series of red beds underlying the Glen Rose. The other is a still older series of shales and limestones with Lower Cretaceous fossils. Several new characteristic micro-fossils are noted from zones in the Trinity.

Introductory Statement

Since the discovery, in the past few years, of oil and gas in horizons of Trinity age, more especially in northern Louisiana, geologists have been much interested in the character, variations, and correlation of this part of the Comanchean series.

There is no doubt that much can be determined as to the subsurface conditions in this area from reliable well data. However, it is thought that a detailed study of the exposures of Trinity rocks in southwestern Arkansas, southeastern Oklahoma, and the northern and central parts of Texas should precede any considerable work on the relations coastward from these outcrops. It is the purpose of the writer to present the results of a preliminary study of these exposures, together with some tentative conclusions regarding subsurface conditions south and east of the outcrop.

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[1]Part of a master's thesis, University of Oklahoma, 1928. Manuscript received by the editor, August 12, 1928.

[2]Humble Oil and Refining Company.

versity of Oklahoma; also to L. P. Teas and W. C. Spooner of Shreveport, Louisiana, for the helpful suggestions and valuable data obtained from them. Much information was taken from the available literature, particularly the works of R. T. Hill, H. D. Miser, and others of the U. S. Geological Survey who are well-known authorities on the Lower Cretaceous of the Gulf Coastal area.

Geography

The area under discussion comprises the northern border of the Gulf Coastal Plain and consists of a belt ranging in width from 5 to 60 miles extending from Pike County, Arkansas, westward through the lower tier of counties in southeastern Oklahoma to Love County, then southward from Red River through Montague, Wise, Parker, Hood, Bosque, and Coryell counties, Texas (west of Waco), a distance of about 420 miles.

There are three salient physiographic features of this northern edge of the coastal plain.

1. The generally low altitude, which ranges from 450 to 650 feet in Arkansas and Oklahoma and from 800 to 1,000 feet in northern Texas.

2. The relatively flat, undulating surface, consisting of broad, flat, alluvial valleys and irregular inter-stream areas with general southeastward slope.

3. A comparatively loose soil, as a rule quite sandy, supporting a dense growth of pine and oak in Arkansas and forming the so-called Cross Timber belt in southern Oklahoma and northern Texas, having a characteristically luxuriant growth of "black jack," a small oak. The limestone and calcareous clay zones in the Trinity group produce a typical black soil known locally as "black-land belts."

The drainage of the area is toward the south and southeast. The principal streams in Arkansas are the Little Missouri, Salina, Cossatot, and Rolling Fork rivers. In Oklahoma, the streams are Little River, Boggy Creek, and Kiamichi and Washita rivers, all tributaries of Red River. In Texas, the streams of the area are Denton Creek, forks of Trinity River, and Brazos and Bosque rivers.

Stratigraphy of the Trinity Group

General statement

The Comanchean (Lower Cretaceous) series of the Gulf Coastal area is divided into three major groups: Trinity, Fredericksburg, and Washita, in ascending order (Fig. 1). This lowest group was first called

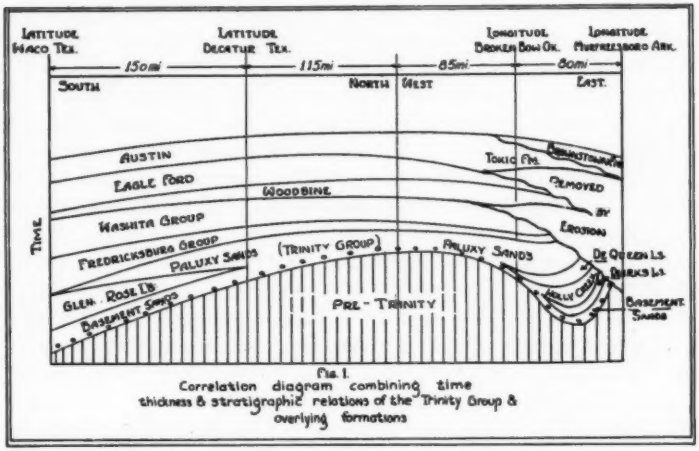

FIG. 1.
Correlation diagram combining time thickness & stratigraphic relations of the Trinity Group & overlying formations

the Bosque division by Taff[1] in his report on the Cretaceous of Texas. R. T. Hill, in his report on the Mesozoic rocks of Arkansas,[2] and later in his classic work on the geology of the Black and Grand prairies of Texas,[3] renamed it the Trinity division. The term Trinity was taken because of the excellent exposures of lower Comanchean along West Fork and Clear Fork of Trinity River, northwest of Fort Worth, Texas. The following table shows in a generalized way the subdivisions of the Trinity group in the area under discussion.

GENERAL SUBDIVISIONS OF THE TRINITY GROUP

Northern Texas	*Southeastern Oklahoma*	*Southwestern Arkansas*
Paluxy sand	Paluxy sand	Paluxy sand
Glen Rose limestone	DeQueen limestone	DeQueen limestone Holly Creek clay Dierks limestone
Basement sands		Basement sands

[1]J. A. Taff, *Texas Geol. Survey 3d Ann. Rept.* (1891), p 280.

[2]R. T. Hill, *Arkansas Geol. Survey Ann. Rept. for 1888*, Vol. 2, p 116.

[3]R. T. Hill, "Geology of Black and Grand Prairies of Texas," *U. S. Geol. Survey 21st Ann. Rept.* (1901), Pt. 7.

In general the rocks of this group consist of conglomerates and gravel beds, sands, clays, marls, limestones, shell agglomerates, and bands of gypsum, anhydrite, and celestite. All of these strata grade into one another laterally and vertically, depending on their proximity to the shore line when deposited. This gradation makes it almost impossible to separate the group into distinct formational units. The northwestern-most exposures are characterized by gray and yellow pack sands above a basal conglomerate. Southward and eastward these sands grade into clays and then into marls and limestones.

The sediments of the Trinity group were deposited in the encroaching Comanchean sea upon the subsiding Paleozoic floor. Presumably, in this area, at least, during most of Triassic and Jurassic time, according to our present understanding, the Paleozoic uplands were peneplaned, permitting a widespread accumulation of sand and silt much like the basal Cambrian beds.

Upon this old peneplaned surface there was laid down a basal conglomerate overlain by coarse sand beds. This basal deposit, as first outlined by Hill[1] and mentioned by later writers, can be traced from central Mexico, where it represents Upper Jurassic time, to the Rio Grande, where it is probably lowermost Comanchean in age, thence, continuously northward across Texas to Red River, where it is the time equivalent of lower Fredericksburg. Although it is a matter of conjecture whether or not the Trinity sea ever extended north of the Wichita-Arbuckle uplift in southern Oklahoma, nevertheless, remnants of the basal sand, equivalent to Washita time, are found in Kansas. Perhaps this northward extension was between the Wichita uplift and the present Rocky Mountain region on the west. The evidence of this transgressive movement northward from the Rio Grande across Texas and Oklahoma is found in the distinct northward overlap of this basal formation over truncated and peneplaned older rocks.

In the Arkansas-Louisiana area there was in progress a slow northeastward transgression, contemporaneous with the Texas submergence. It is thought that the Trinity sea extended across east-central Texas into northern Louisiana, as far east possibly as the present Mississippi River. A continuous subsidence of this basin, especially in northwestern Louisiana, permitted the accumulation of several thousand feet of sediments.

Later, there was a gradual down-warping northward and westward which caused successively younger beds to overlap these older beds

[1] *Op. cit.*

northward, into southwestern Arkansas and, at a still later period, westward into southeastern Oklahoma. This last encroachment of the Trinity sea probably extended no farther than the southern edge of the Ouachita-Arbuckle highlands.

BASEMENT SANDS

NOMENCLATURE

The term Basement sands is here used to designate all gravels and sands deposited in the lower Trinity sea and occurring below the Glen Rose of Texas and the Dierks of southwestern Arkansas. This name was first used by Hill in his report on the Black and Grand prairies of Texas.[1]

Although a definite lithologic unit, the beds of this formation are different in age and merge with basal sands equivalent in age to younger formations of the group. As stated, these basal sands extend from Mexico to the central Great Plains region and range in age from Upper Jurassic to upper Washita. The term "Basement sands," as here restricted, includes only that part of this transgressive basal zone below the Glen Rose beds in northern Texas and below the Dierks limestone in southwestern Arkansas.

DISTRIBUTION

The Basement sands crop out in a belt ranging from 3 to 15 miles in width, and extending from central Texas northward into Wise County, where it loses its identity as a unit because of the gradation into the basal sands equivalent to the Glen Rose and the lower part of the Paluxy sands. In southwestern Arkansas the outcrop of the Basement sands, ranging from 2 to 5 miles in width, as mapped by the writer, extends from Wolf Creek near Antoine, Pike County, westward to northeastern Sevier County, Arkansas, where it merges with basal sands equivalent to the Dierks limestone and overlapping younger beds.

LITHOLOGY AND GENERAL CHARACTER

Considering their broad lateral distribution, the character of the Basement sands is remarkably uniform. The lithologic character is derived directly from the pre-existing rocks which make up the underlying floor. That is, where the underlying Paleozoic rocks are chiefly limestones, the lower part, at least, of the Basement sands consists of fragments of these limestones cemented together to form a conglomerate.

[1] *Op. cit.*

Where the underlying rocks are granitic the Basement sands are arkosic, and so on.

In general, the Basement sands consist of coarse conglomerate or gravel at the base. This basal gravel in some places is composed of large cobbles or boulders; in other localities it is merely coarse sand. Above the basal bed are coarse-grained sands, as a rule friable and poorly consolidated, although in places indurated to form hard ledges of sandstone. Grading upward the sand becomes argillaceous and calcareous and may contain thin lenticular beds of red, gray, or pale-green sandy clay.

In central Texas, on the Llano-Burnet uplift, the Basement sands are very thin and in some places absent, although they thicken within a short distance down the slopes of the uplift, that is, basinward. The basal conglomerate is composed of quartz, sandstone, and limestone fragments, cemented in a matrix of arenaceous and argillaceous lime. The pack sands above are very coarse, stratified, and calcareous, grading into the arenaceous Glen Rose beds above without any appearance of sudden change. The thickness of the whole unit in this area ranges from a few feet to more than 100 feet.

In southeastern Brown County, the formation consists of a conglomerate bed ranging from 30 to 120 feet in thickness, composed of sandstone and limestone pebbles some of which are 4 inches in diameter. This is overlain by 8-40 feet of red, calcareous sand and clay beds.

From Brown County northward the basal conglomerate is generally thin, less than 20 feet, the pebbles are small, well-rounded, siliceous, and consolidated in a sandy matrix. The pack sands overlying are fine-grained and gray or yellow in color.

In southwestern Arkansas the Basement sands have a basal conglomerate of large, well-rounded novaculite and quartz pebbles, which has been called the Pike gravel by Miser and Purdue.[1] They state that the thickness of the gravel ranges from almost nothing to 100 feet. It thins noticeably at several localities in Pike County, north and northwest of Murfreesboro, where headlands of Jackfork and Stanley (Carboniferous) rising above the general pre-Comanchean peneplaned surface, were not completely covered by the gravel. Most of the pebbles are about an inch in diameter, but some are as much as 8 inches. These larger cobbles are restricted to the lower part of the conglomerate. Most of the pebbles are white, gray, red, or black novaculite, derived from the

[1] H. D. Miser and A. D. Purdue, "Gravel Deposits of DeQueen and Caddo Gap Quadrangles, Arkansas," *U. S. Geol. Survey Bull. 690-B* (1918), p 18.

Arkansas novaculite (Devonian ?), exposed with other Paleozoic formations in the Ouachita Mountains on the north. Some of the pebbles are of quartz, chert, and sandstone or quartzite. The proportion of this siliceous material increases westward, particularly in younger basal beds in McCurtain County, Oklahoma.

Many of the gravel beds are distinctly cross-bedded. As a rule they are loose and friable, containing much sand, either as lenses or filling the interstices between pebbles. A few hard conglomerate beds are found where the induration has occurred due to a local cementation by iron oxide. Above the Pike gravel is 20-40 feet of coarse, gray pack sand, massively bedded and with many thin sandy clay streaks.

CONDITIONS OF SEDIMENTATION

The conclusion is reached that the Paleozoic rocks endured a long period of erosion prior to the deposition of the Basement sands. The relative purity and roundness of the sand based on microscopic examinations, indicates that the grains have in all probability been transported long distances and subjected to considerable working and reworking by water and wind.

It is also assumed that the pre-Comanchean floor possessed many minor irregularities and that as the Trinity sea began its invasion, these irregularities were smoothed and lowered by wave-cutting. The major irregularities of this old land surface, which have been positive areas since Paleozoic time, are shown by such remnants as the Wichita-Arbuckle-Ouachita uplift in Oklahoma and Arkansas, and the Llano-Burnet uplift in central Texas.

CONCLUSIONS IN REGARD TO BASEMENT SANDS

Consideration of the Basement sands as a whole leads to certain general conclusions, which have been pointed out by Hill.[1] They are: (1) the age of the beds of this formation differs at different points, according to the location along the slope of the pre-Comanchean floor, and (2) the unit consists of the sandy marginal deposits of many beds, which are well defined in their seaward extensions from a lithologic and paleontological viewpoint, but which collectively present a single unit representing a relatively long period of time.

Further, the Basement sands beneath central Texas and northern Louisiana represent lower Trinity time; basal sands under north-central Texas and southwestern Arkansas were laid down in Glen Rose time; and

[1] *Op. cit.*

the northwesternmost extension of basal sands in southeastern Oklahoma and the Red River area of northern Texas constitutes a part of the Paluxy sands and was formed in latest Trinity time.

GLEN ROSE, DIERKS, HOLLY CREEK, AND DEQUEEN ZONES

NOMENCLATURE

The central part of the Trinity group in southwestern Arkansas and northern Texas consists of shallow-water limestones, clays, bands of gypsum, and celestite, alternating with red clays and sands. In Texas, the name Glen Rose has been given to this zone, because of the good exposures surrounding the town of Glen Rose, Somervell County. In Arkansas the corresponding part of the Trinity group has been divided by Miser and Purdue[1] into the Dierks and DeQueen limestone zones.

DISTRIBUTION

From the Llano-Burnet area in central Texas, northward to Wise County, the Glen Rose outcrop ranges from a few miles to 20 or more in width. South of Weatherford, Parker County, the outcrop is a wide belt, but northward to Decatur, Wise County, it gradually narrows and finally disappears. Where last seen it is a one-foot ledge of calcareous, argillaceous, indurated sandstone with a few fossil casts.

The DeQueen limestones crop out in a narrow, irregular band, less than 2 miles wide, extending from southwestern Pike County, Arkansas, westward into central McCurtain County, Oklahoma. The Dierks limestones are exposed in a similar narrow belt north of the DeQueen outcrop but farther east, that is, from eastern Sevier County, Arkansas, eastward to south-central Pike County. The Holly Creek sands and clays crop out between the Dierks and the DeQueen.

LITHOLOGY AND GENERAL CHARACTER

Glen Rose limestones.—The typical Glen Rose of central Texas consists of even-bedded argillaceous and arenaceous limestones, alternating with gray shales. Most of the beds are very uniform. The fine-grained siliceous material decreases from the base upward, the calcareous content increasing in proportion. In the upper part of the formation the limestones again become arenaceous, grading into the Paluxy sands above. Thus there are three well-defined divisions of the typical Glen Rose in this area. The lower and upper thirds consist of thin-bedded, arenaceous

[1] *Op. cit.*

marls which weather readily, forming gentle slopes. The middle division is composed of thicker and more massive, indurated limestone beds, resistant enough to form a definite escarpment.

In northern Texas the lithology is somewhat different. Instead of the lower central part consisting of nearly pure, thick limestones, it is composed of alternating sand and clay layers with a few thin calcareous partings. This zone thickens northward and pinches out toward the south and east. It probably represents the deposit made during a minor oscillation or rapid withdrawal of the sea along its western margin during middle Glen Rose time.

The thickness of the Glen Rose increases south and east of the outcrop. The amount of divergence is not the same in different sections, but its average is about 8½ feet per mile. As shown in cross section *CC'*, Weatherford-Fort Worth-Dallas (Figs. 2 and 3), the Glen Rose thickens from 120 feet in the outcrop near Weatherford to more than 800 feet as shown by well logs at Dallas, 68 miles east, or a divergence of 10 feet per mile.

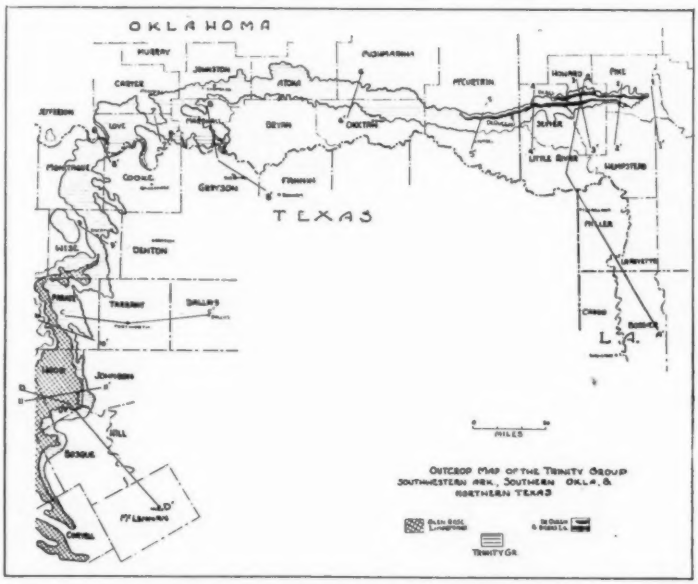

FIG. 2.—Outcrop map of the Trinity group, southwestern Arkansas, southern Oklahoma, and northern Texas, showing Glen Rose limestones, DeQueen and Dierks limestones; and showing locations of sections of Figures 3 and 4.

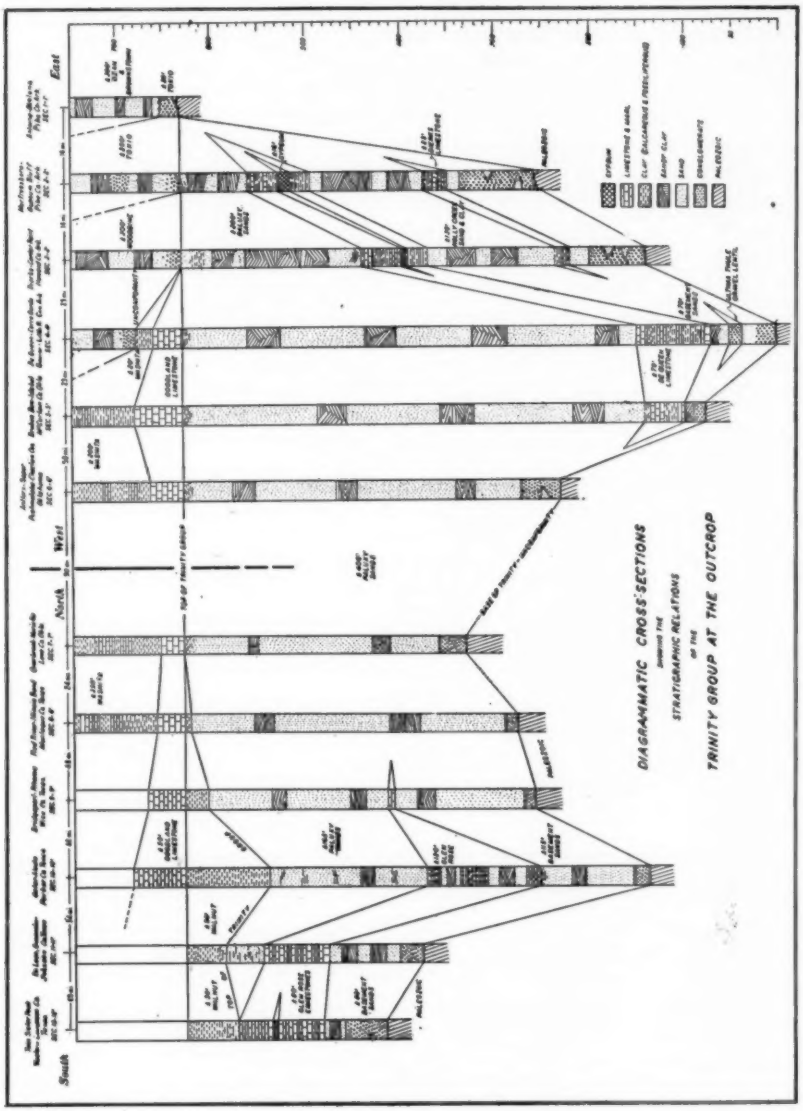

FIG. 3.—Diagrammatic cross sections showing the stratigraphic relations of the Trinity group at the outcrop. Locations of sections are shown on Figure 2. Vertical scale in feet.

The formation as a whole forms a rather prominent cuesta between the gentle slopes of the Paluxy sands above and the flat area of outcrop of the Basement sands below. The limestones are as a rule bluish-gray on fresh fracture, but where exposed to weathering the color changes to buff-yellow, due, perhaps, to oxidation of the magnesium and iron. Taff is reported to have described the occurrence of celestite in the Glen Rose, in Burnet County. Hill[1] described occurrences not only of celestite but also of strontianite, aragonite, epsomite, and other salts from the Glen Rose in the Lampasas-Burnet area and anhydrite in Comanche and western Parker counties.

Dierks limestone.—The Dierks limestone lentil which occurs immediately above the Basement sands in southwestern Arkansas has a maximum thickness of 40 feet. The limestone layers in the central part are extremely hard, crystalline, grayish in color, and are intercalated with thin shaly layers. All of the beds are very arenaceous, particularly the lower and upper parts, which grade into the Basement sands below and the sandy clays of the Holly Creek above, respectively.

DeQueen limestones.—Most of this zone consists of greenish-yellow calcareous clays and yellowish-gray arenaceous marl and limestone layers, ordinarily less than a foot in thickness. Near the central part are layers of gypsum and here and there some celestite. The best exposure of gypsum is at Plaster Bluff on the Little Missouri River, 3 miles southwest of Murfreesboro, Arkansas. Here the gypsum beds have an aggregate thickness of 16 feet. Westward about 15 miles, north of Center Point, Arkansas, the same zone is only 3 feet thick. At this locality the celestite occurs as thin, lenticular layers in the clays below the gypsum zone. Most of the clays above and below the gypsum beds are gypsiferous, grading into the pure, massive layers of satin spar and saccharoidal gypsum. Southward the gypsum changes to anhydrite. In northwestern Louisiana it ranges from 300 to 500 feet in thickness and is known as the "Anhydrite zone."

At the type locality northeast of DeQueen, Arkansas, the formation attains a maximum thickness of 74 feet at the outcrop. It thins westward into Oklahoma, is only 40 feet thick north of Broken Bow, and finally disappears in western McCurtain County. Southward into Louisiana the DeQueen thickens, and with the Dierks forms a thick series of limestones, the Glen Rose.

Holly Creek zone.—Between the Dierks and DeQueen zones occurs a series of red clays, thin sand beds, and gravel lenses. One gravel lentil

[1]R. T. Hill, *U. S. Geol. Survey 21st Ann. Rept*, Pt. 7, p 146.

in particular, whose maximum thickness is 40 feet, has been named the Ultima Thule lentil.[1] It occurs locally just above the Dierks lentil. This entire series of red, non-fossiliferous, arenaceous rocks ranges from almost nothing to 300 feet in thickness. As the Dierks limestone, below, pinches out westward in Sevier County, these overlying beds merge with the Basement sands. It should be noticed that this is a part of the well-defined westward overlap of the successively younger beds of the Trinity group in this area. Southward from the outcrop, this red series thins within a short distance and is represented in Louisiana by limestones which form a part of the Glen Rose.

It seems desirable that this series of beds, occurring between two such well-defined marine zones, should have a distinct name. It is here proposed that the name Holly Creek be used. This term is chosen because of the excellent exposures of these clays and sands near Little Holly and Holly creeks, southeast of Dierks, Howard County, Arkansas.

CONDITIONS OF SEDIMENTATION

The Glen Rose limestones conformably overlying the Basement sands were developed probably because of the continued subsidence of the pre-Comanchean floor, giving greater depths to the invading Trinity sea. These deposits of clays and limestones are very arenaceous, and many of them alternate with thin sand layers, indicating oscillatory and unsettled conditions of deposition. During periods of calm, perhaps, lime muds were forming in shallow water near the shore. This would have permitted the formation of a stratum of limestone or marl. At some later time, there might have been a storm period during which the high waves and strong currents rolled the beach sand seaward, spreading it out over the limy mud. This would have formed a stratum of sand and siliceous silt above the limestone layer. As such conditions continued, alternating layers of limestone and clay or sand were deposited on the sea bottom. A considerable thickness of sandy material between two limestone beds would indicate that the shore line had retreated for a time, then had advanced again rapidly. Such a sand body would thicken shoreward and pinch out seaward.

Presumably, the greater amount of shaly material in the DeQueen of Arkansas indicates that conditions were less oscillatory than in northern Texas at the same time. This is also evidenced by the greater quantity of siliceous material along the western and northwestern border of the Glen Rose outcrop.

[1] H. D. Miser and A. D. Purdue, *U. S. Geol. Survey Bull. 690-B*, p 18.

In central and eastern Texas and in northwestern Louisiana, the beds of this age consist of nearly pure limestones, indicating deeper and more quiet water. The thickest section of the Trinity group so far recorded is in the area of the Sabine uplift of Louisiana. It is thought that this particular region was the deeper part of an extensive basin during most of Trinity time, and that as it subsided more and more deposits were formed within it.

The occurrence of thick beds of gypsum in the middle of the fossiliferous DeQueen at the outcrop in Arkansas, and the extremely thick zone of anhydrite which occupies a similar position in the Glen Rose in northwestern Louisiana, are two important features to be noticed in this part of the section. In offering an explanation for these conditions it is necessary to review briefly several general facts. The normal order of deposition in a shallow arm of the sea or a nearly inclosed basin, where concentration by evaporation takes place, is: (1) iron hydroxide (limonite), if present, (2) calcium carbonate (limestone), (3) calcium sulphate, ordinarily deposited in anhydrous form (anhydrite), according to Grabau,[1] and (4) sodium chloride (salt), if concentration continues. From experimental study it has been learned that this normal order of deposition may vary. The factors that may alter or change the forming of these precipitates are: presence of chloride ions, the amount of carbon dioxide in the air and in the water, and the seasonal temperature variations.

Applying this to the problem at hand, we assume that following the deposition of the limy muds in lower DeQueen time, conditions were favorable for the precipitation of calcium sulphate. Probably, much of this material was originally laid down in the anhydrous form. Such being the situation, the gypsum at the outcrop in Arkansas is only the weathered product in a shallow zone, analogous to the examples of alteration of anhydrite to gypsum near the surface cited by Rogers[2] and Udden.[3] Or, perhaps conditions fluctuated so that alternating layers of gypsum and anhydrite were formed; or, taking the other extreme, we might assume that all the material was originally precipitated as gypsum. In any case, the burial beneath hundreds and thousands of feet of later sediments supplied an ample physical environment for the dehydration and conversion of the entire calcium-sulphate body to a continuous and thick zone of anhydrite.

[1] A. W. Grabau, *Principles of Stratigraphy*, p. 537.

[2] Rogers, *Economic Geology*, Vol. 7 (1912), p. 186.

[3] J. A. Udden, *Bull. Geol. Soc. Amer.*, Vol. 35, pp. 345-54.

The deposits of Glen Rose time reach their maximum development south of the outcrop, probably in northwestern Louisiana and East Texas. So far, the greatest thickness of Glen Rose is in the Sabine uplift of Louisiana. This area was covered by an extensive arm of the Trinity sea, and in these shallow waters, with climatic conditions probably warm and arid, and the water saturated with sodium chloride, these thick beds of calcium sulphate were laid down. The concentration of the water was probably never great enough to cause the precipitation of the sodium chloride, at least in the area of anhydrite as indicated. So far, no salt has been found in the Glen Rose or the DeQueen.

PALEONTOLOGY

The Glen Rose and Dierks-DeQueen zones of the Trinity group are as a rule fossiliferous. The fauna appears to be typical in that none of the Paleozoic or early Mesozoic forms carry through into the Comanchean; furthermore, few of the Trinity fossils continue into the Fredericksburg. The life of this epoch was essentially shallow-water in character, as only near-shore, littoral forms have been found preserved in these rocks. The micro-fauna includes only the more hardy forms, particularly the ostracods.

Table I shows the occurrence of the larger fossils (megascopic) and their relative abundance at six outcrop localities. All of these occur rather plentifully in both the Glen Rose and the DeQueen. *Ostrea franklini* Coquand and *Glauconia branneri* Hill have been found in well cores in the Glen Rose formation, in northwestern Louisiana.

Table II shows the species and varieties of micro-fossils and their occurrence and relative abundance in the Trinity. It is to be noticed that *Foraminifera* occur sparingly and those indicated are all members of the family *Miliolidae*. A few of these have been indentified generically, but it has been impossible in this paper to identify these forms specifically. It is thought that at least some of them will prove good markers, after a more detailed study of additional material.

The seeds of *Chara* (a calcareus alga) found in the DeQueen of Arkansas as noted on the micro-faunal list, are also reported from the Glen Rose of northern Texas[1] and from rocks of corresponding age (Purbeck-Wealden) in England.[2] As these fruits are found in many rocks of different geologic ages, their value as horizon-markers is greatly lessened.

[1]W. M. Winton, "Geology of Denton County, Texas," *Univ. of Texas Bull. 2544* (1925), p. 64.

[2]Rupert T. Jones, "On the Ostracoda of the Purbeck, with Notes on Those from the Wealden," *Quart. Jour. Geol. Soc.*, Vol. 41 (1885), p. 337.

TABLE I

MACRO-FOSSILS OF THE TRINITY GROUP*

	Gypsum Bluff, Arkansas	*Messers Creek, Arkansas*	*Dierks, Arkansas*	*Broken Bow, Oklahoma*	*Marietta, Oklahoma*	*Weatherford, Texas*
Anomia texana Hill	Common	Common	Occasional	.....	.....	Occasional
Astarte sp. undet.	.....	.....	Occasional	.....	.....	.....
Avicula sp. undet.	.....	Occasional	.....	Rare	.....	.....
Barbatia parva missouriensis Hill	.....	.....	Occasional	.....	.....	.....
Buccinopsis parryi Conrad	.....	.....	.....	.....	.....	Rare
Cardium servierensis Hill	.....	Common	Common	.....	.....	.....
Corbicula arkansaensis Hill	Abundant	.....	Common	Abundant	.....	.....
Cucullaea gratiota (Hill)	.....	.....	.....	.....	.....	Abundant
Cucullaea sp. undet.	.....	.....	Common	.....	.....	Occasional
Cyprina medialis Conrad	Common	Common	.....	.....	.....	Occasional
Eriphyla pikensis (Hill)	.....	.....	Occasional	.....	.....	Rare
Exogyra texana Roemer	.....	.....	.....	.....	Occasional	Occasional
Exogyra virgula Goldfus	.....	.....	Common	.....	.....	.....
Glauconia branneri Hill	Abundant	Occasional	.....	Common	.....	Abundant
Glauconia bilineri (Neum)	.....	.....	.....	Rare	.....	.....
Glauconia sp. undet.	.....	.....	Occasional	Common	.....	Common
Gryphea sp. undet.	.....	.....	.....	.....	Occasional	Occasional
Lunatia pedernalis (Roemer)	Common	.....	.....	.....	.....	Common
Modiola branneri Hill	.....	.....	Occasional	.....	.....	.....
Mytilus tenuitesta Roemer	.....	Occasional	.....	Rare	.....	.....
Natica sp. undet.	Common	.....	.....	Rare	Rare	Occasional
Nerinea sp. undet.	.....	Occasional	Rare	Common	.....	Occasional
Neritina sp. undet.	.....	.....	.....	.....	.....	Rare
Nucula sp. undet.	.....	.....	Occasional	.....	.....	.....
Ostrea camelina (Cragin)	.....	.....	.....	.....	.....	Occasional
Ostrea crenulimargo Roemer	.....	Rare	.....	.....	Occasional	.....
Ostrea franklini Coquand	Rare	Abundant	Common	Abundant	.....	Rare
Ostrea ragsdalei Hill	.....	.....	.....	.....	.....	Common
Ostrea roemeri Quenstedt	.....	Rare	.....	.....	.....	Occasional
Pecten duplicostata Roemer	.....	Occasional	Rare	Rare	Rare	Occasional
Pleuromya sp. undet.	.....	.....	.....	.....	Occasional	Rare
Protocardia sp. undet.	.....	.....	.....	.....	.....	Common
Serpula paluxiensis Hill	.....	Occasional	Rare	.....	.....	Occasional
Trigonia sp. undet.	.....	.....	.....	.....	Rare	Occasional

*H. C. Vanderpool, "Fossils from the Trinity Group (Lower Comanchean)," *Jour. of Paleontology*, Vol. 2, No. 2 (June, 1928), p. 96.

TABLE II

MICRO-FOSSILS OF THE TRINITY GROUP*

	DeQueen, Gypsum Bluff, Arkansas	*DeQueen, Messers Creek, Arkansas*	*Glen Rose, Northwest Louisiana*	*Lower Marine Zone, Northwest Louisiana*	*Glen Rose, Weatherford, Texas*
Ostracoda					
Bairdia dorsoventrus n. sp.	Common	Common	Occasional	.....	Abundant
Bairdia glenrosensis n. sp.	Occasional	Rare	Rare	.....	Abundant
Bythocypris rotundus n. sp.	Common	Abundant	Common	Rare	Abundant
Cypridea diminutus n. sp.	Abundant	Common	Rare	.....	Occasional
Cypridea tuberculata Sowerby, *gypsumensis* n. var.	Abundant	.....	.....	.....	.....
Cypridea ventrosa Jones, *bispinosus* n. var.	Common	Occasional	.....	.....	Rare
Cypridea sp. undet.	.....	.....	.....	Occasional	.....
Cytheridea trinitiensis n. sp.	Abundant	Abundant	Occasional	.....	Abundant
Cythere ornata n. sp.	Occasional	Occasional	.....	.....	Occasional
Paracypris weatherfordensis n. sp.	Common	Common	Occasional	Rare	Abundant
Pontocypris perforata n. sp.	Rare	Rare	Occasional	Rare	Common
Foraminifera and other forms					
Glauconia branneri Hill	.....	.....	Occasional	.....	Occasional
Massilina sp. undet.	.....	.....	Occasional	.....	.....
Nerinea sp. undet.	.....	.....	Rare	Common	Occasional
Orbitolina af. *texana* Roemer	.....	.....	Occasional	.....	.....
Quinqueloculina sp. undet.	Rare	.....	Common	.....	.....
Spiroloculina sp. undet.	.....	.....	Occasional	.....	.....
Seeds of *Chara* (calcareous alga)	Occasional	.....	Rare	.....	.....

*H. C. Vanderpool, "Fossils from the Trinity Group (Lower Comanchean)," *Jour. of Paleontology*, Vol. 2, No. 2 (June, 1928), p. 97.

The *Ostracoda* are represented in the Trinity micro-fauna by a relatively large number of genera and species and by many individuals. The ostracods as a class evidently have been able to thrive very well under conditions decidedly unfavorable for the existence of other forms of life, especially the microscopic forms. Conditions during the Trinity epoch which were in all probability unsuited for most minute organisms, may account for the paucity of *Foraminifera*.

Bairdia dorsoventrus n. sp., *Bythocypris rotundus* n. sp., *Cytheridea trinitiensis* n. sp., and *Paracypris weatherfordensis* n. sp., are some of the more typical and characteristic ostracods of the Glen Rose-DeQueen.

CONCLUSIONS IN REGARD TO CORRELATIONS

The limestones and clays of the Glen Rose and Dierks-DeQueen zones are the deeper-water deposits formed during the mid-Trinity encroachment of the Comanchean sea. The gypsum in the DeQueen at the outcrop is the shallow-zone weathered product of anhydrite, and the anhydrite occurring southward from the outcrop is the product of calcium-sulphate material precipitated under favorable conditions in a shallow arm of the sea that extended through northwestern Louisiana and southwestern Arkansas.

The tabulated lists of megascopic and microscopic fossils from the DeQueen and Glen Rose at the outcrop not only show a definite relationship between the two units, but offer valuable evidence in their correlation. Most of the species and varieties listed are restricted vertically to these mid-Trinity rocks. The correlation is further aided by the wide lateral range of many of these fossil forms.

The use of *Orbitolina texana* Roemer, a foraminifer, and *Glauconia branneri* Hill, a minute gastropod, is well known by paleontologists of the Gulf Coastal Plain, and these two forms alone are usually taken as unmistakable evidence of the Glen Rose. *Glauconia branneri* occurs in the upper part of the Glen Rose (above the anhydrite in northwestern Louisiana), and *Orbitolina texana* in the lower part. The close relationship between the Louisiana Glen Rose and the typical Glen Rose of central Texas is therefore evident. The DeQueen as exposed in Arkansas probably corresponds with part of the upper Glen Rose of Louisiana (*Glauconia branneri* zone).

LOWER ZONES IN NORTHWESTFRN LOUISIANA

In northwestern Louisiana, below the lower Glen Rose, occurs a thick series of fine arenaceous beds ordinarily reddish in color and, to all

appearances, non-marine. The presence of mica flakes and particles of lignitic material suggests deposition along marshlands or on a delta. The fine material of these beds indicates that the bordering land which was the source of these sediments was of small relief. These red beds, which attain a thickness of 2,000 feet or more in the northern part of the Sabine uplift, thin northward into Arkansas.

This lower red-bed zone overlies and overlaps a series of fossiliferous, gray to black shales and limestones (Section *A-A'*, Fig. 4). These marine beds do not crop out in Arkansas and have only recently been known to exist. The Humble Company's deep test in the Bellevue field, Louisiana, about 30 miles northeast of Shreveport, and stratigraphically the deepest well ever drilled in Louisiana, is, so far, the only test that has penetrated this lower part of the Trinity section.

It has been reported[1] that Pennsylvanian or possibly even Devonian fossils have been found in samples from this new marine horizon, but the writer still believes that these beds are Comanchean in age. Unfortunately this well was abandoned after penetrating 15 feet of gray, non-fossiliferous sand below these marine beds. This might have been only a break in the marine zone, or it may represent the upper part of the Trinity basal sands. In any case, it is probable that a few hundred feet more would have revealed pre-Trinity rocks. Cores from these lower marine beds contain *Ostrea franklini* Coquand, a typical lower Cretaceous fossil, as well as ostracods and other forms which are characteristically post-Paleozoic.

PALUXY SANDS

NOMENCLATURE

The use of the term Paluxy, to include that portion of the Trinity group above the Glen Rose in northern Texas, is well known and needs no mention here. However, the equivalent of the Paluxy in the Arkansas-Oklahoma area, overlying the DeQueen, has never been recognized. Further, the term "Trinity sand" of Taff,[2] Bullard,[3] and others, applied to the westward continuation of these upper sands through southeastern Oklahoma and the northward continuation of the Paluxy into the Red River region, has been confusing. The implication of the

[1] L. P. Teas, "Geology of Bellevue Field, Louisiana," in *Structure of Typical American Oil Fields*, Vol. 2, Ms., citing T. W. Staunton of the U. S. National Museum, P. V. Roundy of the U. S. Geol. Survey, and Alva C. Ellisor of the Humble Oil and Refining Company.

[2] J. A. Taff, *U. S. Geol. Survey Folio, Atoka Quadrangle* (1901).

[3] F. M. Bullard, *Oklahoma Geol. Survey Bull. 39* (1926), p 20.

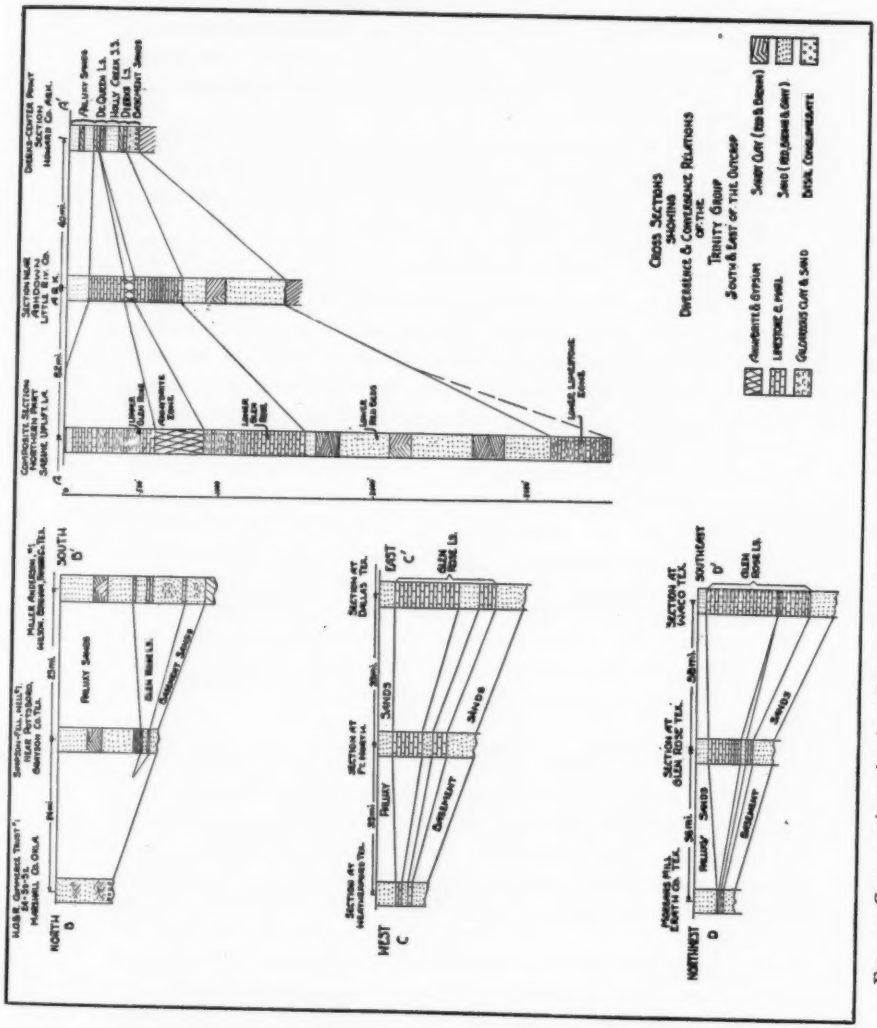

FIG. 4.—Cross sections showing divergence and convergence relations of the Trinity group south and east of the outcrop. Locations of sections are shown on Figure 2. Vertical scale in feet.

name is that these particular sands represent the whole of the Trinity group. This is not the fact. The definite westward overlap of the upper part of the Trinity over the lower part in Oklahoma and Arkansas, cited by Miser[1] and well illustrated in Figure 1 and Figure 3, establishes the age of these upper sands as latest Trinity, that is, younger than Glen Rose-DeQueen time.

It is here proposed that the name Paluxy be used for these upper sands which form a definite lithologic unit, extending from Pike County, Arkansas, westward through southeastern Oklahoma into the typical Paluxy sands of northern Texas.

DISTRIBUTION

In northeastern Burnet County, Texas, a thin sandy bed about 15 feet thick occurs above the Glen Rose limestones and probably represents the most southerly exposure of the Paluxy. However, it cannot be readily differentiated without investigation farther north in eastern Comanche County. There the sand is 50 feet thick. At Weatherford, Parker County, it has increased to 120 feet and attains a maximum of 190 feet in southern Wise County.

In central McCurtain County, Oklahoma, the Paluxy sands are exposed in a broad belt ranging from 6 to 8 miles in width. Eastward the width narrows considerably and beyond Plaster Bluff, Pike County, Arkansas, the sands are absent, the DeQueen being unconformably overlain by Tokio gravels, much younger than Trinity in age (Fig. 3). West of Broken Bow, Oklahoma, where the DeQueen pinches out, these sands form a continuous outcrop across the southern margin of the state to Ardmore, Carter County; thence, southward across Red River into northern Texas.

LITHOLOGY AND GENERAL CHARACTER

The lower part of the Paluxy of Texas is calcareous and contains many thin marl beds. In the upper part, the sand becomes argillaceous and in places consists of pure clay. The sand itself is fine-grained, homogeneous, poorly consolidated and highly cross-bedded. Fragments of silicified wood commonly occur. The color of the weathered material is yellow or white-gray. The Paluxy sands are, in general, more calcareous and less ferruginous than the Basement sands. In Oklahoma and Arkansas, most of the Paluxy consists of fine-grained, friable, gray to yellow sands, locally ferruginous. These pack sands are highly cross-bedded. They contain a few thin partings of gray or red sandy clay. A

[1]H. D. Miser, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), p. 445.

few indurated ledges of sandstone are noticeable along the outcrop where the sand grains have been cemented by iron oxide.

CONDITIONS OF SEDIMENTATION

Although of less areal extent than the Basement sands, these upper sands of the Paluxy nevertheless mark an important horizon. They indicate a rapid retreat and subsequent advance of the sea following Glen Rose time. Little is known of the extent, thickness, or character of the Paluxy in northeastern Texas (north and east of Dallas), but it is thought to cover at least a part of that area. Southward, the Paluxy formation does not extend beyond Brazos River, south of Waco.

In southwestern Arkansas conditions in Paluxy time were somewhat similar, although the rapid oscillation of the sea may not have been so marked. The gradual downwarping of the Arkansas-Oklahoma area westward, after mid-Trinity time, caused the sea to be extended toward the northwest. Thus, the sandy marginal deposits of this advance overlapped the westward extension of the DeQueen limestones and clays.

The greatest thickness of these beds is near Broken Bow, Oklahoma, where they are nearly 500 feet. This area probably represents the central portion of the depositional basin during Paluxy time in the Arkansas-Oklahoma region.

CONCLUSIONS REGARDING PALUXY SANDS

The Paluxy sands mark a hiatus in the marine Comanchean section. The lower part was deposited in the regressive Trinity sea that retreated beyond the line delimiting sandy sediments. The upper part of the Paluxy was laid down in the transgressive Fredericksburg sea. This hiatus represents a considerable time interval, sufficient to have accounted for marked changes in the fauna. The fact that *Exogyra texana* and *Ostrea crenulimargo* are present in the upper part of the Trinity at the section at Marietta, Oklahoma, indicates that this part of the Paluxy has a much closer affinity to the Fredericksburg than to the Trinity. As stratigraphic divisions, for the most part, are based on paleontologic evidence, it would be possible to include the uppermost part of the Paluxy sand in the Fredericksburg group.

STRUCTURE

The general structure of the Trinity rocks, in a part of the area under discussion, is indicated on the accompanying map (Fig. 5), the contours being drawn on the base of the Trinity, relative to sea-level.

In mapping the structure of southeastern Oklahoma it has been found that the best marker to use is this contact between the loose, coarse, nearly horizontal, sand and gravel beds of Mesozoic age above, with indurated and commonly highly-folded shales, sandstones, and limestones of Paleozoic age below. Such a break can hardly escape notice even in a more or less carelessly-kept well record.

Another good marker, in working subsurface structure in this area, is the top of the Trinity (Paluxy sands), or the base of the Goodland limestone (Fredericksburg). This change from more than 20 feet of good solid limestone above, to red, gray, or yellow sandy clays and water sands below, is evident in most logs.

Almost all of the major folds in the Paleozoic rocks, such as the Criner Hills uplift, Preston and Cooke County anticlines, are gently reflected in the overlying Trinity rocks. Perhaps this is a matter of later compaction and warping of the Mesozoic beds to conform to older Paleozoic folds and topography rather than of post-Trinity folding.

The most important structural features to be noticed on the map are: the so-called Cooke County anticline or "Ellenburger high," south of Red River in northern Texas; the Marietta syncline in Love County, Oklahoma; the Criner Hills-Preston anticline extending from the region south of Ardmore, Carter County, in a southeastward direction through Marshall County, Oklahoma, into Grayson County, Texas (the Preston and Cooke County anticlines are nearly parallel and occur at the 90° change of strike of the Trinity and Fredericksburg rocks in this region); the Madill anticline or "nose;" the Durant syncline; and the Choctaw anticline in central McCurtain County.

In the Oklahoma-Arkansas boundary area the dip at the base of the Trinity ranges from 80 to 125 feet per mile. In the Red River region of south-central Oklahoma and northern Texas the normal regional dip of this contact ranges from 40 to 60 feet a mile.

The cross sections *A-A'* and *B-B'* on the map (Fig. 5) show the relation of the Trinity group to overlying and underlying beds, as evidenced by well records and samples.

General Summary

As stated, it has been the writer's purpose in this paper to study the several units of the Trinity Group along the outcrop, preliminary to an attempt at any work on the subsurface stratigraphy, south and east of these exposures.

A comparison of the surface sections, their lithologic characters, and fossils has led to several conclusions. A distinct unit, the Holly Creek,

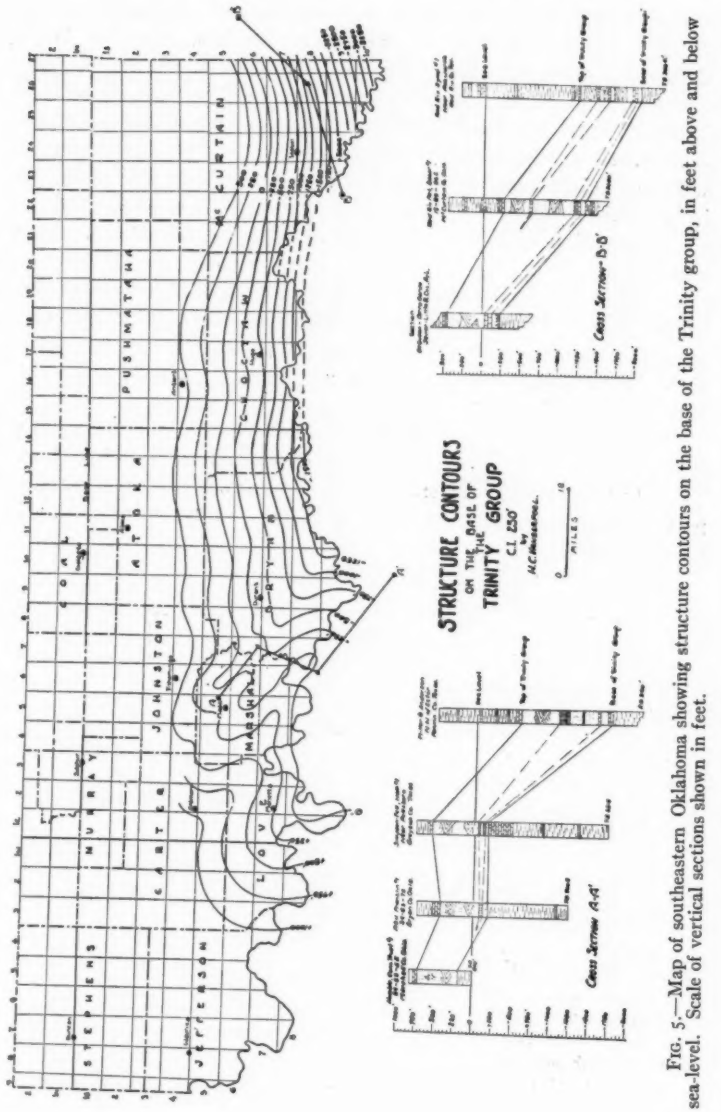

FIG. 5.—Map of southeastern Oklahoma showing structure contours on the base of the Trinity group, in feet above and below sea-level. Scale of vertical sections shown in feet.

has been named and defined in the southwestern Arkansas section. Another definite lithologic unit, the Paluxy, has been recognized in the Oklahoma-Arkansas section. The DeQueen-Dierks interval in southwestern Arkansas has been correlated with the Glen Rose of northern Texas. The DeQueen and Dierks have been considered stratigraphically equivalent to and correlative with the upper Glen Rose of the northwestern Louisiana section. The Holly Creek red clay and sand zone between the DeQueen and Dierks loses its identity southward and is replaced by limestones forming a part of the upper Glen Rose, as just mentioned.

A thick series of red sandy clays and sands is present in northwestern Louisiana, which is not exposed in Arkansas because of a northward overlap. These red beds overlie and overlap a still older series of fossiliferous shales and limestones, below which are gray sands which may represent the Trinity basal sands.

In conclusion, the attempt has been made to show the general group relations of the rocks of the Trinity epoch in central and northern Texas to those of southeastern Oklahoma, southwestern Arkansas, and northwestern Louisiana, both by stratigraphic descriptions and graphic illustrations.

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AN INVESTIGATION OF THE PROBLEM OF THE ESTIMATION OF GAS RESERVES[1]

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ABSTRACT

The purpose of the writer is to contribute to the solution of gas problems by direct application of the laws governing the movement of gas through porous media. Also, a correction is given for the determination of pressure at depth.

Different methods are in use for the estimation of subterranean gas reserves. One of these consists in calculating the total pore space of the rock containing the gas, and multiplying this by the prevailing pressure of the gas. That is simply an application of Boyle's law to the gas in the pool. This method is called the "saturation method" by R. W. Brown,[3] the "porosity acreage method" by C. P. Parsons,[4] and the "pore space method" in the *Manual for the Oil and Gas Industry*.[5] The "equal pound loss method," which is based on a similar principle, has lately been discussed by R. H. Johnson and L. C. Morgan.[6]

The pore space method has been worked out by E. W. Shaw,[7] who also considered the amount of gas remaining in the pool after abandonment. In the *Manual*[8] mention is made of the following factors which

[1]Manuscript received by the editor, August 28, 1928.

[2]Adviser to the Bataafsche Petroleum Maatschappij, 394 Frankenslag.

[3]R. W. Brown, *Valuation of Oil and Gas Lands*, 1st edition. New York, 1924, pp. 176-81.

[4]C. P. Parsons, "Accurate Estimates of Gas Reserves," *The Oil and Gas Journal*, May 10, 1928, p. 86.

[5]Treasury Department of the U. S. Internal Revenue, *Manual for the Oil and Gas Industry under the Revenue Act of 1918* (Revised, August, 1921). Washington, 1921, pp. 32-39.

[6]R. H. Johnson and L. C. Morgan, "A Critical Examination of the Equal Pound Loss Method of Estimating Gas Reserves," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), pp. 901-04.

[7]E. W. Shaw and P. L. Ports, "Natural Gas Resources Available to Dallas and Other Cities of Central North Texas," *U. S. Geol. Survey Bull. 716* (1920), pp. 55-90.

[8]Treasury Department of the U. S. Internal Revenue, *op. cit.*, p. 33.

make this method difficult of application: the difficulty of ascertaining accurately the thickness and lateral extent of the reservoir, the porosity of the rock, the effect of encroaching water and oil, and the quantity of gas remaining when the limit of commercial production is reached. A further factor which can be added to this list is the quantity of gas that will be liberated from the edge water and oil as pressure declines.

Restricting our investigation to the initial quantity of gas contained in the reservoir, we must consider the lateral extent of the reservoir before depletion has begun, the thickness of the porous bed, the porosity, and the initial pressure of the gas.

Let A be the lateral extent in units of area, T the thickness in units of length (the unit of area being the square of this unit of length), and μ the average porosity of the rock; then the volume of the pores within the reservoir is expressed by:

$$\mu TA \qquad (1)$$

and this is the volume the gas occupies at the prevailing reservoir pressure p.

According to Boyle's law this amount of gas will occupy, at atmospheric pressure, a volume:

$$\mu TAp \qquad (2)$$

An investigation of the problem of the flow of gas through the capillary spaces of a porous stratum leads to a method of estimating the value of

$$\mu T \qquad (3)$$

in formula (2). This can be obtained from the results of pressure records of closed-in wells, and from the measured production of one well which can be opened or closed at will. This last well will be called "the venting well."

It will be assumed that the gas-bearing stratum is perfectly level and of uniform thickness and porosity, and that the lateral extent of the pool is unlimited. In the vicinity of the venting well the pressure of the gas will be diminished; because of this, the gas will expand but in the pores no cooling will result, all work performed by the expansion being converted into heat through internal friction, and the process is isothermal. Further, we will disregard all deviations from Boyle's law and neglect the effect of adsorption.

The flow of an incompressible liquid through capillary tubes follows Poiseuille's law,[1] which is proved by O. E. Meyer[2] to hold good for gases. Darcy's experiments and many experiments on a large scale[3] have since proved that Poiseuille's law also applies to the flow of water through the pores of a sand.

With this in mind we may deduce that Darcy's law for water flowing through sand also determines the motion of gases through sand.

For an incompressible liquid we may write Darcy's law as follows:

$$q = \frac{Ka}{\eta}\frac{dp}{dx} \tag{4}$$

where p is the pressure head expressed in atmospheres, x the distance measured in a direction opposite to that of motion (Fig. 1), K a constant, depending on the characteristics of the sand, η the coefficient of internal friction of the liquid, and a the number of units of power per unit of area exerted by the pressure of one atmosphere, q the volume of liquid which flows through the unit of area in the cross section.

The coefficient of internal friction η may be defined as the force necessary to move a plane surface of a unit of area past a similar face at a unit distance away, at the unit rate of speed.

In a gas, as was proved by Meyer, the internal friction is independent of the pressure; therefore, instead of (4) we may write for a gas:

$$\frac{V}{p} = \frac{Ka}{\eta}\frac{dp}{dx} \tag{5}$$

V being the volume occupied at atmospheric pressure by the gas passing in a unit of time through the unit of area of the cross section.

The equation (5) may also be written:

$$V = \frac{Ka}{\eta}\, p\, \frac{dp}{dx} \tag{6}$$

Suppose the producing string of the venting well has perforations throughout the whole thickness of the sand. Let the well be closed and

[1] J. Versluys, *Le Principe du mouvement de l'eau souterraine.* Amsterdam, 1912, pp. 11-31.

[2] O. E. Meyer, "Ueber die innere Reibung der Gase," *Ann. der Phys. und Chemie*, CXLVIII, 1873.

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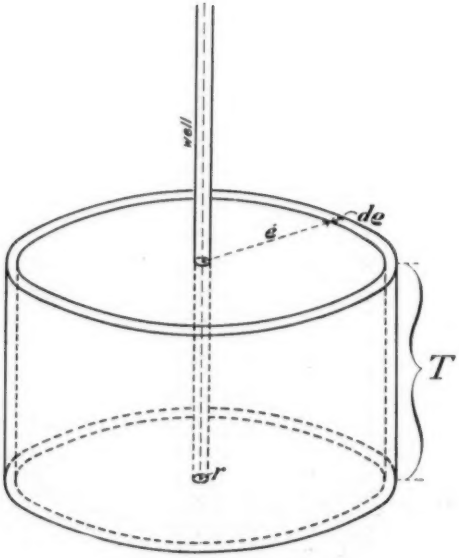

FIG. 2

FIG. 1

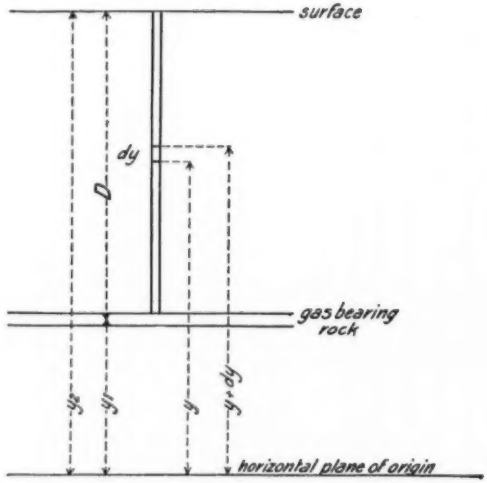

FIG. 3

FIGS. 1-3

we start with a uniform pressure in the whole area. As soon as the well is opened the pressure in the rock is diminished in the vicinity of the well and the gas will travel toward it. Now we may assume that the decline of pressure is the same at all points at the same distance away from the venting well. By opening and closing this well we are able to induce different distributions of pressure, but at any point at a given distance, ρ, from the axis of the well, the pressure must be the same.

Under the prevailing pressure p a unit of volume of the porous rock will contain a quantity of gas which will occupy a volume:

$$\mu p \tag{7}$$

at atmospheric pressure.

If the time be represented by t, the amount of gas in the part of the gas-bearing rock included between two cylindric surfaces generated by the revolution of two vertical lines about the axis of the well with radii ρ and $\rho + d\rho$ (Fig. 2) will increase during a time dt by a quantity occupying at atmospheric pressure a volume:

$$2\pi\rho T\mu d\rho \frac{\partial p}{\partial t} dt \tag{8}$$

According to equation (6) the quantity of gas passing in the unit of time through the internal cylindric surface here described, at atmospheric pressure, will occupy a volume:

$$2\pi\rho T \frac{Ka}{\eta} p \frac{\partial p}{\partial \rho} \tag{9}$$

and the gas passing in a time dt at atmospheric pressure, a volume:

$$2\pi\rho T \frac{Ka}{\eta} p \frac{\partial p}{\partial t} dt \tag{10}$$

If we differentiate (10) with respect to ρ, we will find the differential of the quantities of gas, measured at atmospheric pressure, passing in a time dt through the outer and inner cylindric surface. This differential is expressed by:

$$2\pi T \frac{Ka}{\eta} \left[p \frac{\partial p}{\partial \rho} + \rho \left(\frac{\partial p}{\partial \rho} \right)^2 + \rho p \frac{\partial^2 p}{\partial \rho^2} \right] d\rho dt \tag{11}$$

This volume must be equal to that expressed by (8), both representing the volume at atmospheric pressure of the amount of gas by which

the quantity of gas between the two cylindric surfaces increases in the differential of time dt. Dividing (8) and (11) by $2\pi T d\rho dt$ we get the equation:

$$\mu\rho \frac{\partial p}{\partial t} = \frac{Ka}{\eta}\left[p \frac{\partial p}{\partial \rho} + \rho \left(\frac{\partial p}{\partial \rho}\right)^2 + \rho p \frac{\partial^2 p}{\partial \rho^2}\right] \tag{12}$$

If from a set of wells not too far apart within a certain range of distance all are closed but one, and this one well, the venting well, is manipulated by opening and closing a valve, we are able to make the pressure, p, vary with the time, t, and with the distance, ρ, from the venting well. This venting well constitutes a center of low pressure.

Reading the pressure in the closed observation wells, we ascertain the relation of pressure to time at various distances from the center of low pressure.

For every well, pressure may be plotted against time and a curve can be drawn expressing the relation of pressure to time at known distances away from the venting well. By the aid of this curve the value of $\frac{\partial p}{\partial t}$ can be obtained for various values of ρ and for various values of t.

In the same way, the value of p being measured at various times in all the observation wells, the pressure can be plotted against the distance from the venting well, for any value of t.

This will procure a set of curves expressing for any desired value of t the relation of p to ρ. With the aid of these curves we can construct curves giving the relation of $\frac{\partial p}{\partial \rho}$ and $\frac{\partial^2 p}{\partial \rho^2}$ to ρ.

Equation (12) can be transformed as follows:

$$\mu \frac{\eta}{Ka} = \frac{\frac{p}{\rho}\frac{\partial p}{\partial \rho} + \left[\frac{\partial p}{\partial \rho}\right]^2 + p \frac{\partial^2 p}{\partial \rho^2}}{\frac{\partial p}{\partial t}} \tag{13}$$

In this equation we can substantiate arbitrary values of p and ρ and at the same time the corresponding values of the derivatives, and we find a figure for

$$\mu \frac{\eta}{Ka} \tag{14}$$

η is the coefficient of internal friction of the gas which can be determined, and a is a certain number depending on the units we have chosen. K, however, is a constant depending on the characteristics of the rock, which can not easily be determined directly from samples.

Returning to formula (9), we can deduce a relation of the amount of gas, yielded by a well at constant flow, to this same constant K; the thickness of the porous bed and values we can ascertain directly.

The formula (9) expresses the volume of gas passing in the unit of time through a cylindric surface generated by the revolution of a vertical line about the axis of the venting well with a radius ρ. If this volume:

$$U = 2\pi\rho T \frac{Ka}{\eta} p \frac{\partial p}{\partial \rho} \tag{15}$$

is independent of the time and of the distance, it is the volume the well yields per unit of time at unvaried flow.

We can separate the variables in this equation as follows:

$$\frac{U}{2\pi T} \frac{\partial \rho}{\rho} = \frac{Ka}{\eta} p \partial p \tag{16}$$

and integrating we obtain the expression:

$$\frac{U}{2\pi T} \log \frac{\rho_2}{\rho_1} = \frac{Ka}{\eta} \frac{p_2^2 - p_1^2}{2} \tag{17}$$

which can be thus transformed:

$$T \frac{Ka}{\eta} = \frac{U}{\pi(p_2^2 - p_1^2)} \log \frac{\rho_2}{\rho_1} \tag{18}$$

Substituting for U the production of the venting well, for p and ρ, respectively, the pressure at the bottom of this well and its radius, and for p_2 and ρ_2, the pressure in another well and the distance from this venting well to the opened well, we find the value of $T \frac{\eta}{Ka}$

Multiplying the first member of (13) by the first member of (18) we get:

$$\mu T \tag{19}$$

and the constant K is eliminated.

This product represents the total pore volume per unit of area in the pool. Generally the values of p and ρ in (13) are different from p_2 and p_1, respectively ρ_2 and ρ_1 in (18). Substituting arbitrary values p_3 and ρ_3 in (13) we dissolve the product μT by the multiplication of the second members of the equations (13) and (18).

$$\mu T = \frac{\left[\frac{p_3}{\rho_3}\frac{\partial p_3}{\partial \rho_3} + \left|\frac{\partial p_3}{\partial \rho_3}\right|^2 + p_3\frac{\partial^2 p_3}{\partial \rho_3^2}\right] U \log\frac{\rho_2}{\rho_1}}{\pi\frac{\partial p_3}{\partial t_3}(p_2^2 - p_1^2)} \qquad (20)$$

This form multiplied by the initial reservoir pressure and the area underlain by the gas pool will yield an estimation of the amount of gas originally contained in the subterranean reservoir. Of course we cannot avoid the difficulty of estimating the areal extent of the pool, but by applying this method, an average of the product:

porosity × *thickness*

is ascertained, probably more accurately than by measuring the porosity of different samples and the thickness of the porous rock.

The Boyle law does not hold true for most natural gases.[1] If the observed deviations of this law are expressed as a function of the pressure p, we can correct formula (4) and we are able to deduce a more complicated formula instead of (20).

Dissolving U from equation (17), we get:

$$U = \frac{\pi KaT}{\eta}\frac{p_2^2 - p_1^2}{\log \rho_2 - \log \rho_1} \qquad (21)$$

In order to make this formula an expression of the open-flow condition of a well, for p_1 we must substitute the pressure at the bottom of the well and for p_2 the reservoir pressure.

In this case ρ_2 is an unknown value, thousands of times greater than ρ_1. As long as the rock pressure has not declined very much, we may write:

$$U = \frac{\pi KaT}{\eta}\frac{p_r^2}{\log \rho_2} \qquad (22)$$

[1] G. A. Burrell and J. W. Robertson, "The Compressibility of Natural Gas and Its Constituents, with the Analysis of Natural Gas from 31 Cities in the United States," *U. S. Bureau of Mines Tech. Paper 158* (1917).
C. P. Parsons, *op. cit.*

where p_r is the reservoir pressure. So the reservoir pressure, and, as a result, the amount of gas still remaining in the pool, would be roughly proportional to the square root of the open-flow capacity of a well.

We can simplify equation (21):

$$U = constant \times (p_2^2 - p_1^2) \tag{23}$$

Thus, if the initial rock pressure has been determined and also the open flow capacity of the well as production commences, we can calculate the value of the constant in formula (23). If the number of wells does not change we can afterward, using this same formula, by substituting the value of the constant ascertained at the beginning, compute from the open flow the rock pressure still remaining. We must keep in mind that p_1 is the pressure at the bottom of the venting wells.

Generally it is accepted that the pressure exerted by the weight of the gas in a well may be neglected, which means that the pressure at the bottom would be the same as the pressure at the head of the well. This, however, is not by any means the situation in deep wells, where great pressures occur. The specific gravity of the gas under a high pressure can not always be neglected.

The correction to be applied to the measured gas pressure at the head of a well, in order to find the pressure at any given point in the well, can be simply deduced. If the pressure at a height y above a certain level in the well (Fig. 3) is p atmospheres, and the specific gravity of the gas j, then the pressure exerted by the column of the gas enclosed between the levels y and $y + dy$ in units of power per unit of area is:

$$pjdy \tag{24}$$

If the pressure of one atmosphere is equal to a units of power per unit of area, we may write:

$$pjdy = -adp \tag{25}$$

or

$$dy = -\frac{a}{j}\frac{dp}{p} \tag{26}$$

Integrating this equation between the limits y_2 and y_1, respectively p_2 and p_1, we get:

$$y_2 - y_1 = -\frac{a}{j}\log\frac{p_2}{p_1} \tag{27}$$

and if y_1 and y_2 be taken for the heights of the gas-bearing stratum and the head of the well, $y_2 - y_1 = D$ is the depth of the well. So:

$$D = \frac{a}{j} \log \frac{p_1}{p_2} \tag{28}$$

or:

$$p_1 = p_2 e^{\frac{Dj}{a}} \tag{29}$$

Hitherto p_1 and p_2 have been expressed in atmospheres; this formula (29), however, holds if any other unit of pressure be chosen.

If D be expressed in meters, then $a = 10.33$ and the pressure p_1 in the gas-bearing sand would be computed from the formula:

$$p_1 = p_2 e^{\frac{Dj}{10.33}} \tag{30}$$

in which p_2 is the pressure in the closed well, measured at the surface, j the specific gravity of the gas in grams per cubic centimeter and D the depth of the well in meters. If the depth be expressed in feet and the specific gravity in pounds per cubic foot this formula becomes:

$$p_1 = p_2 e^{\frac{Dj}{2093.6}} \tag{31}$$

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GEOLOGICAL NOTES

BASEMENT ROCKS ENCOUNTERED IN A WELL IN FLORIDA

A well of more than usual interest has recently been completed in Florida. This boring as a test for oil or gas was begun September 13, 1926, by the Ocala Oil Corporation in the center of Sec. 10, T. 16 S., R. 20 E., Marion County, Florida. The location is 16 miles west-southwest of Ocala, or about 3 miles south of York. Drilling was continued until July, 1928, since which time operations have been suspended on account of unsuccessful attempts to recover or sidetrack lost tools. The total depth attained was 6,180 feet.

Through the coöperation of the general manager, W. J. Flesher, the Florida Geological Survey was supplied with cuttings at intervals from the surface to a depth of 2,480 feet. From this depth to the bottom of the well samples from wide intervals only are represented, Fortunately, however, sufficient cuttings are on file in the Florida Geological Survey offices to form a fairly complete record. These have been studied for their fossil content by G. M. Ponton, assistant geologist, and to a lesser extent for their mineralogical content by James H. C. Martens, assistant geologist. More detailed studies of the samples as a whole are to be made.

A considerable area in central peninsular Florida is included within a large structural "high" shown on the geological maps of the state and discussed in the reports on the geology and structure. In this area the Ocala limestone of Eocene age is the controlling formation and where not actually at the surface lies close to it. Because of this fact the territory is generally referred to as the Ocala uplift region. The well under consideration is located probably a little south of the highest point of the uplift as mapped on the top of the Ocala limestone as exposed or encountered in drilling. The Ocala is a soft, easily weathered limestone, and its use, particularly the use of its top, as a key bed may lead to somewhat inaccurate detail.

The first 30 feet at the well consisted of sand, clay, and flint, partly residual, immediately beneath which the Ocala Eocene limestone was entered. Limestones predominated, as indicated by the samples, to a depth of more than 3,800 feet. Unfortunately, samples from below 2,420 feet were taken only at wide intervals, and furthermore it is neces-

sary to make a detailed study of many of the microscopic fossils before differentiating the geologic horizons or zones through which the well passed. The first definitely recognizable Cretaceous was in the sample from 3,260 feet, but it is probable that the Cretaceous will be found somewhat higher.

The last sample from this well in which any fossils were observed came from a depth of 3,970 feet. In the interval from 3,970 feet to 4,750 feet only two samples were procured labelled as to specific depth, although five others were obtained covering wide depth ranges. Somewhere between the depths of 3,970 feet and 4,245 feet the well passed out of the sedimentary formations and into metamorphic rocks. The cuttings within the interval mentioned consist of micaceous schist, slate, and quartzite. The age of these basement rocks has not been determined, but the Cretaceous in Alabama and Georgia is underlain by crystalline Paleozoic rocks.

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TALLAHASSEE, FLORIDA
October, 1928

DISCUSSION

THE AGE OF THE DIATOM-BEARING SHALES AT MALAGA COVE, LOS ANGELES COUNTY, CALIFORNIA

RESUMÉ

The Malaga Cove diatom-bearing shales are believed to be upper Miocene in age, equivalent to upper Monterey, the correlation having been based on paleontologic evidence. The shales are believed to have accumulated in shallow water.

R. D. Reed has recently given an excellent description and discussion of the exposure of shales on the sea cliff at Malaga Cove, a few miles south of Redondo, Los Angeles County, California.[1] Unfortunately he was not able to present a very conclusive statement as to the age of the diatom beds in question because he lacked exact paleontologic data. The following notes have been assembled in order to supply this deficiency in so far as published information will permit.

It so happens that the diatoms of the locality under consideration have been subjected to intensive study by some of the world's foremost authorities on these organisms, and this affords a basis for comparison with the type locality of the Monterey shale near Monterey, a deposit which likewise has been carefully worked. The history of the discovery of the deposit at Malaga Cove is extremely dramatic and forms an interesting chapter in the annals of west American paleontology. Briefly, the facts are here given.

In March, 1876, T. P. Woodward, in the employ of the Coast and Geodetic Survey, picked up a piece of float diatomite on the beach "about four miles south of Santa Monica, California." The block, the size of a cigar box, was sent to Henry G. Hanks in San Francisco, a well known mineralogist of a preceding generation and an active member of the San Francisco Microscopical Society. Portions of the material were sent to interested students of diatoms in many parts of the world, without, however, a suspicion of the extreme interest they were to arouse. From all quarters came letters pronouncing the material the most astounding ever known, from the standpoint of number of species and purity of the samples. The letters were invariably accompanied by requests for more bulk samples.

One of these early samples fell into the hands of Charles Stodder of Boston, Massachusetts, who prepared a paper on the deposit in 1878.[2]

An attempt, therefore, was made by the society to obtain an additional supply. A half barrel was procured from somewhere in the Los Angeles region,

[1] R. D. Reed, "A Siliceous Shale Formation from Southern California," *Jour. Geol.*, Vol. 36, No. 4 (May-June, 1928), pp. 342-64, 4 text figs.

[2] "Notes on Diatomaceæ from Santa Monica, California," *Amer. Jour. Micr.*, Vol. 4 (1878), pp. 13-15.

but, much to the disappointment of all, it proved to be relatively worthless. (We now know that the large sample must have come from a lower horizon in the Miocene, stratigraphically.) After that, many but futile attempts were made to locate the source of the original block, but up to 1893 it remained a mystery. In that year Henry C. Hyde[1] published most valuable historical notes, from which the present resumé has been largely drawn.

The original location of the float block was announced in 1897 by Schultze and Kain[2] as "sea cliffs 10 miles south of Redondo." The distance given is evidently an error, because the Malaga Cove exposure is the only known sea cliff outcrop of diatomite between Redondo and Point Fermin, near San Pedro. A comparison of material collected by Dr. Reed at Malaga Cove with the lists of diatoms from the original Santa Monica float block certainly indicates the identity of age of the two and makes it very probable that Schultze and Kain were correct in their conclusion. They gave a list of 244 species, all presumably from the Malaga Cove locality. Tempere and Peragallo[3] have published a list of about 150 species and subspecies of diatoms, the locality being given simply as "Redondo, fossil." The original source of this material could hardly have been other than Malaga Cove, and may have been obtained through Schultze or Kain. This list agrees so well with those of "Santa Monica" that it might well pass for one of them.

In March, 1928, I presented a paper[4] on the Monterey shale at the type locality before the meeting of the American Association of Petroleum Geologists. In the paper I assembled a list of the names of all species of diatoms recorded in the literature from the type Monterey. The total was 171 species and subspecies. On checking these against the published lists of "Redondo" —Malaga Cove—"Santa Monica" diatoms I find that 78 per cent have been so reported. In doing this I have made no attempt to correct errors of identification, preferring to leave this subject for special treatment. But the similarity of the material from the two places when properly cleaned and mounted is most striking. All of the common species at Monterey are likewise common species at Malaga Cove with practically no exception. The prediction is ventured with considerable assurance of its correctness that when the Monterey list is properly corrected it will contain less than 10 per cent of species not also found at the southern locality.

The logical conclusion to be drawn as to the age of the diatom-bearing shales at Malaga Cove is that they are the exact or almost the exact equivalent of the upper part of the Monterey shale at the type locality of that formation. The evidence, I believe, completely refutes the meager stratigraphic data which

[1] "The Santa Monica Diatomaceæ," *Trans. San Francisco Micr. Soc.*, Pt. 1 (all published), 1893, pp. 18-24.

[2] E. A. Schultze and C. Henry Kain, "The Santa Monica Diatomaceous Deposit with List of References to Figures and Species," *Bull. Torrey Bot. Club*, Vol. 24, No. 1 (Nov. 30, 1897), pp. 496-504.

[3] *Diatomees du Monde Entier*, Ed. 2, 1908, pp. 24-26.

[4] "The Monterey Shale of California at Its Type Locality with a Summary of Its Fauna and Flora," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 10 (October, 1928), pp. 969-83.

has led a few geologists to believe that the Malaga Cove diatom shales and their near-by equivalents may be lower Pliocene in age. If they be placed in Pliocene, then it will be necessary to place the type Monterey in the same epoch, but such a correlation does not conform to any accepted designation heretofore made.

As to the bathymetric conditions under which the organic shales were laid down at Malaga Cove, Dr. Reed presents the conflicting evidence deduced from published statements. The opinion seems to be widespread that the presence of *Radiolaria* in a sedimentary deposit indicates profound depth of water during deposition. This view doubtless followed upon the discovery of radiolarian oozes under abysmal conditions by some of the oceanographic expeditions. The organisms are not uncommon in the shallow waters along our shores to-day, and there is no reason to suspect that they did not occur under similar conditions during the Miocene. Some of the California siliceous shales containing *Radiolaria* in notable numbers are so situated that it is impossible to picture any great depth of water during deposition. Such, for instance, is the case of the Temblor shales within half a mile of basement granite on the east side of the San Joaquin Valley. The *Silicoflagellata* are all pelagic, so far as known, and may drift into shallow water or deep. They are not uncommon in the surf at certain seasons at Copalis Beach, Washington. If the presence of pelagic organisms be indicative of great depth, then it will be necessary to assume that this condition existed practically through the Pliocene and Pleistocene in the Los Angeles Basin, because *Globigerina*, a pelagic foraminifer, is common in the shales of these ages.

The diatoms themselves furnish most conclusive evidence that the Malaga Cove deposit accumulated in shallow water. The genera *Arachnoidiscus* and *Cocconeis* are exceedingly common in some of the shales and they grow *attached to sea weeds!* Many of the other common genera are shallow-water, bottom-dwelling forms, unknown in the great depths of the sea.

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September 13, 1928

THE DATE OF THE MAJOR DIASTROPHISM AND OTHER PROBLEMS OF THE MARATHON BASIN, TRANS-PECOS TEXAS

There have recently appeared two excellent papers, the one by Professor Charles Schuchert[1] and the other by Philip B. and Robert E. King,[2] which discuss Marathon basin problems. The principal new interpretations afforded by these papers are two: (1) the assignment of the date of most intense deformation to the interval between the Pennsylvanian and Permian, instead of within

[1] "The Pennsylvanian-Permian Systems of Western Texas," *Amer. Jour. Sci.*, (5), Vol. 14 (1927), pp. 382-401.

[2] "The Pennsylvanian and Permian Stratigraphy of the Glass Mountains," in *Contributions to Geology, 1928, Univ. of Texas Bur. of Econ. Geol. Bull. 2801* (1928), pp. 109-45.

the Pennsylvanian, as stated by the reviewer;[1] (2) the inclusion within Udden's original Gaptank formation of the strata which the reviewer called in the field the Dugout beds, and originally grouped, on very questionable grounds, with the Tesnus formation.[2]

The reasons assigned for the first of these new interpretations are not entirely convincing, and those for the second are scarcely more satisfactory than the reviewer's original interpretation. It may be said concerning the second new interpretation that here these later investigators have hit upon perhaps the weakest of many vulnerable spots in the reviewer's original presentation. It has been a matter of considerable perplexity that other published criticisms of the original work have not been forthcoming earlier, since the problems of the Marathon basin are difficult enough to be of real interest to any geologist and should long since have aroused the mettle of the more enterprising.

(1) The reviewer's original statement was based on the fact that he had found highly deformed beds of either the Tesnus or Haymond formation bevelled by erosion and overlain by a nearly flat-lying basal conglomerate of the Gaptank formation, directly above which were found strata containing *Chonetes mesolobus* and other distinctly Pennsylvanian fossils. This conclusion is now questioned, the statement being made that the Haymond grades conformably up into the Gaptank without any difference in dip and strike and with no basal conglomerate at the junction of the two.

The crucial area is the summit portion of the low and broad anticline of Gaptank strata which extends from the low hill on the Marathon-Fort Stockton road at a point 2 miles S. 10° W. of Gap Tank eastward, to the lower slopes of the escarpment of the Comanchean rim rock. It is true that in the very heart of the anticline along the road, the Tesnus or Haymond is arched and strikes parallel with the basal Gaptank strata. South of this arch, however, the basal bed of the Gaptank, wherever it can be actually found, is a conglomerate, and directly under the basal Gaptank bed the strata of Tesnus or Haymond dip more steeply and strike irregularly and at great variance with the strike of the basal Gaptank. There are, also, other facts to be considered.

(a) The lower part of the original, true Gaptank of Udden contains several thick, coarse conglomerates, as shown in the King brothers' section on pages 116 and 117 of their paper. These conglomerates are much coarser and more extensive than the conglomerates known in any lower formations in the area. Particularly is this true of a thick conglomerate cropping out in a shallow draw a short distance southeast of the anticlinal hill on the Marathon-Fort Stockton road. This conglomerate consists of angular and subangular clearly detrital blocks as large as 2 feet in diameter in a heterogeneous mass indicating rapid deposition by powerful currents.

(b) The lower true Gaptank contains pebbles and boulders of Tesnus or Haymond sandstones and quartzites, clearly indicating erosion of the lower strata and redeposition in the lower Gaptank. There is no proof that the sands and shales of at least the lower Gaptank were not derived from those of the

[1] "Geologic Exploration of the Southwestern Front Range of Trans-Pecos Texas," *Univ. of Texas Bull. 1753* (1917), pp. 110-11.

[2] *Idem*, pp. 103-05.

Tesnus or Haymond. We know no other source for the sands. It should be remembered that the Tesnus and Haymond are in general poorly consolidated and hence easily disintegrated by weathering and erosion. This is the reason why the pebbles and boulders of Haymond or Tesnus in the lower Gaptank conglomerates are fewer than those of the more consolidated, more resistant Dimple formation. Also, the most of the sands and clays derived from erosion of Tesnus and Haymond would be likely to be swept farther out to sea than the pebbles and boulders.

(c) The fact that there are very numerous large boulders of undoubted Dimple strata in the lower Gaptank conglomerates indicates vigorous erosion of the Dimple during or previous to lower Gaptank deposition.

(d) The true Gaptank of Udden is not so highly deformed as closely adjacent older formations. The true Gaptank is exposed only in a low, broad anticline and the King brothers admit that at the contact with the Permian on the north flank of the anticline no difference in dip and strike between Gaptank and Permian (Wolfcamp) can be detected, nor is any basal conglomerate known to overlie the true Gaptank. So far as we know at present, there is certainly a greater break within the Permian at the base of the Hess formation than the merely possible break between Wolfcamp and Gaptank.

Of course, the intense deformation must cease somewhere and may do so very abruptly. The point, however, is that this has not yet been proved in connection with the Gaptank anticline. A narrow zone on the north flank of that anticline has approximately vertical dips, but these may represent a fault or abrupt monocline along an underlying zone of weakness; the axis of the Gaptank anticline at the foot of the eastern bluffs exhibits some faults of relatively small displacement. Dr. Beede and the reviewer found the Wolfcamp faulted previous to the deposition of the Hess conglomerate along a dip valley between the Wolf Camp and Gap Tank localities. The Gaptank may have been folded into an anticline at some time subsequent to Wolfcamp deposition, either in pre-Hess, pre-Leonard, or post-Tessey time. In other words, there was probably some successive shifting of site of deformation northward with the progress of time.

(e) The assignment of the major diastrophism to some time within the later Pennsylvanian rather than to the close of that period corresponds better with events in New Mexico and Oklahoma. In the former state the unconformity comes between the Magdalena and the Abo and at least the lower Abo is faunally of Cisco Pennsylvanian age. The deltaic deposits of Cisco and Wichita age flanking the Arbuckle and Wichita mountains of Oklahoma imply a previous uplift in those mountain areas. Similarly arkoses are found in the upper Cisco of the Panhandle. This argument will have more weight with the periodicists than with the reviewer, since the latter knows major diastrophism in North America in every geologic period.

(2) The grouping of strata west of the town of Marathon with the Gaptank seems to be based on the facts that both are marine and have in common several long-ranging Pennsylvanian fossils. Lithologically the strata of the two localities show more differences than resemblances. Strata west of Marathon have no coarse, heavy conglomerates; the sandstones are different and have none of the typical gray limestone beds of development comparable with

those of the true Gaptank. The greatest resemblance is in the shales. It is impossible to trace the true Gaptank westward into the strata west of Marathon, since a wide belt of alluvium-covered territory intervenes. It is also improbable that the strata west of Marathon, called Gaptank by these authors, can be traced laterally into other strata, since they are bounded on the west by an extensive alluvial plain, on the southeast by an overthrust, and on the northwest by unconformably overlying Permian.

The reviewer originally grouped these strata with the Tesnus because they lithologically resemble that formation more than any other known formation. He still thinks it possible that they may be a marine equivalent of the Tesnus, although of late years he has been more inclined to consider them, at least in part, the equivalent of the Strawn of central Texas, which they resemble to a greater extent both faunally and lithologically than any other known formation in central Texas.

Although originally reluctant to publish a new formation name for these strata, the reviewer, who was the first to describe them and to collect and identify fossils from them, will now propose for them the name Dugout beds, his original field name. The term "beds" is used advisedly, since they may be found to be either a facies, member, formation, or series.

If the Dugout beds are really older than the Gaptank, which the reviewer still holds to be true, most of the evidence for placing the major diastrophism between the Pennsylvanian and the Permian must be disregarded.

Other problems.—There remains the possibility of another important unconformity in the Paleozoic; conglomerates in the Tesnus, in what the Kings refer to the Haymond, and in the Dugout strata, may mean a post-Dimple unconformity in the Marathon basin contemporaneous with the unconformity between the Bend and the Strawn in central Texas and the pre-Franks unconformity in Oklahoma. This possible unconformity may correlate with the extensive overlapping of the Magdalena upon Basement complex and the older Paleozoic rocks in the eastern ranges of New Mexico.

The origin of the sands in the Tesnus, Haymond (?), and Dugout is an unsolved problem. If derived from the Ordovician or Cambrian, these formations must then have been uncovered. They may have been derived from a Basement complex land area flanking the present Marathon basin area, more probably on the southeast. Or it is possible they came from sedimentary formations how unknown but belonging to the Silurian, Devonian, or Mississippian.

The validity of the Haymond as a distinct formation is yet uncertain. It appears to be the exact lithologic counterpart of the Tesnus. It may be overthrust on the Dimple. In the Alps and Pyrenees the overthrusting occurred before a part of the folding, and this is true also in southeastern Idaho. There is the possibility that where the supposed Haymond occurs the time of folding may have been a little later than that of the folding in the central and southeastern parts of the Marathon basin. The deformation in the Marathon basin may have been initiated as early as the end of Dimple time and never wholly ceased until post-Tessey time, the major movements being pre-Gaptank. This also corresponds with events in the Alps and Pyrenees.

Professor Schuchert thinks the intrusives in the Glass Mountains are of the date of first deformation of the Cretaceous rocks. This is not certain, since Böse found similar syenites intruded in the Permian at Las Delicias, Coahuila, Mexico, and previous to the deposition of the Trinity Cretaceous. In most of the southwest igneous rocks of that general composition are later than the granites and rhyolites and in Arizona and New Mexico are supposed by Lindgren to be mid-Tertiary.

Dr. van der Gracht was perhaps the first to criticise the reviewer's assignment of the age of folding of the Cretaceous rocks and overlying lavas on the west margin of the Marathon basin to a later date than the Laramide. There is much to be said in favor of this criticism, but the exact age cannot be proved stratigraphically, since no indubitably Tertiary strata are known. From the standpoint of physiographic development, the doming of the Cretaceous rocks rimming the basin probably occurred long subsequent to the Laramide movements and very possibly is as late as the Lafayette.

One of the most important problems of the Marathon basin is that of the Ordovician succession. With the exception of the Maravillas chert, all the known Ordovician rocks are incompetent. A full succession of Ordovician strata might be found in the troughs of the synclines, but none is exposed there. In all the known anticlines and anticlinoria the Ordovician and Cambrian rocks have been greatly stretched. Strata have been sheared out in the stretching. It is significant that in the least strongly deformed anticline of the area—1½ miles northeast of the junction of Pena Colorada and Maravillas creeks—there is perhaps the thinnest known section of the Ordovician, consisting, so far as known, only of the upper Ozarkian and the uppermost Ordovician stages. This may mean that the major folding was subsequent to the major thrust movements. Practically nothing can now be taken for granted in the Ordovician succession. The lithologic succession and subdivision must be based on the faunas, and much patient labor with the hammer must yet be accomplished before a possible full succession of the Ordovician is known. This is not very likely to be found at any one place, since there is widespread shearing-out of strata. Since faunal zones now known are scattered fairly well throughout almost the whole of the Ordovician, there is great probability that almost the whole of the Ordovician was represented by deposits and, indeed, perhaps all of it. Yet some of the zones may never be found in the exposures. There remains the chance that subsequent work will find the representatives of different Silurian, Devonian, and Mississippian stages.

The Caballos novaculite formation exhibits at many places in the southeastern part of the basin a succession of two novaculites and two variegated, predominantly greenish, chert members. In other places some of these members are lacking, because of (1) non-deposition, (2) the shearing-out of part of the section, or (3) erosion previous to Tesnus time.

The Tesnus in the more intensely deformed synclines is in many places closely crumpled and cut by intra-formational shear faults. The older formations in the anticlines are sheared to a greater extent. Many of the zones suggested as conglomeratic in the original work are doubtless shear-thrust breccias. In some of these, decisive criteria of brecciation can be discovered, but in others—perhaps the most—it is difficult to distinguish breccias positively, since the

limestone fragments have been greatly corroded and the cherts in either alternative are notably angular. In some places the occurrence of slickensiding is a partly distinctive criterion suggesting brecciation by shearing, but it is a criterion which must be used with great caution in the absence of other distinctly confirmatory evidence, since shearing is quite likely to take place in true conglomeratic zones.

The problems are by no means insuperable. Careful, detailed, patient work—especially extensive collecting of fossils—will ultimately solve most of them. Still, subsequent experience in other extensively thrust areas has not served to diminish the reviewer's original very wholesome respect for the complexity of the structural and stratigraphic problems. It is indeed fortunate that none of the strata is greatly metamorphosed. Without doubt the pre-Permian rocks of the Marathon basin exhibit as interesting structural problems as any unmetamorphosed succession known or likely ever to be known anywhere on the North American continent.

CHARLES LAURENCE BAKER

HOUSTON, TEXAS
September 20, 1928

REVIEWS AND NEW PUBLICATIONS

Petroleum and its Products. By WILLIAM A. GRUSE. Mellon Institute Technochemical Series. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York, 1928. viii + 377 pp., 7 figs., many tables. Cloth. 6 × 9 inches. Price, $4.50.

The United States leads all other countries in the total and yearly production of petroleum. Its premier position is due in no small part to its remarkable progress in the invention and perfection of oil-field equipment of all kinds. Drilling and pumping machinery has had rapid development in the United States. Nowhere else in the world is there such an elaborate system of pipeline facilities for the transportation of oil. Discovery and improvement of refining processes of almost inestimable value are credited to scientific genius in this country. Yet there is a real need for publication of comprehensive texts and treatises on some of the most important technical phases of the petroleum industry.

In prefacing his new book, *Petroleum and its Products*, just published by McGraw-Hill, William A. Gruse is probably quite justified in stating that he "has been moved to write this book by the lack of collected information on petroleum chemistry in the English language, particularly that assembled from the standpoint of the American industry." A further quotation from the preface indicates the author's purpose. "Gurwitsch's admirable work, *Wissenschaftliche Grundlagen der Erdölverarbeitung*, has recently become available through a translation by Moore. The translation, however, retains the viewpoint of the original, and does not supply the information on American petroleum which Gurwitsch lacked. Nor is this offered by the various excellent American treatises on petroleum technology. The author has therefore set down such information as he has collected, as well as some of his beliefs, surmises and doubts, about subjects related to petroleum chemistry, in the hope that they will be useful to the many investigators now beginning scientific studies of petroleum in this country and elsewhere.

The author has grouped the sixteen chapters under three heads. Ninety-three pages are given to the descriptions of petroleum, 117 to refining, and 210 to utilization. An ample index of 37 pages completes the volume.

This book is a chemical discussion of the properties, refining, and utilization of petroleum. It contains information especially valuable to engineers concerned with the refining of petroleum. Petroleum engineers in general, who have enlarged their spheres of usefulness to include administrative positions with producing and refining companies, should not consider a work like this of value only to the chemist. The thoroughly grounded and well rounded geologist recognizes nothing less than the whole earth as his field of activity.

J. P. D. HULL

TULSA, OKLAHOMA
September 20, 1928

Petroleum. By ALBERT LIDGETT, editor of *The Petroleum Times*, London. Isaac Pitman & Sons, 2 W. 45th Street, New York, 1928. Third edition, revised and enlarged. 160 pp., 37 illus. Demy 8 vo., cloth gilt. Price, $1.50.

Petroleum is a handy little volume written in fluent and non-technical style by the editor of *The Petroleum Times*. Because of his long experience as an oil-trade journalist in watching and recording the growth of the industry, Mr. Lidgett is well able to present the essential facts in an agreeable manner for general reading. No technical discussions are attempted, although some scientific data are presented in diagrams showing the steps in refining processes, and in tables of temperature and gravity conversions. The statistical appendix contains production figures of the oil-producing countries of the world through 1927.

The author uses the historical method in describing the different phases of the industry, and, although naturally setting forth the facts from the British point of view, he gives suitable space and credit to the methods in operation and importance of production in the world's oil-producing countries. In a general way the subjects presented are the origin, natural distribution, production, refining, transportation, and uses of petroleum. One chapter is devoted to the oil-shale industry and another to the extraction of petroleum from coal.

In these world-wide days when every well-informed person is supposedly conversant on many more topics than he used to be, he may not be surprised to have a popular treatise on petroleum recommended for the extension of his five-foot shelf, especially as petroleum has attained such a vitally important place in industrial, social, political, and military life. The ordinary man may be surprised to learn how little he knew about the ramifications of petroleum. The geologist might refresh his memory on the broader aspects of the industry by looking through this book.

J. P. D. HULL

TULSA, OKLAHOMA
September 19, 1928

"Geology of the Naparima Region of Trinidad (British West Indies)." By VINCENT CHARLES ILLING. *The Quarterly Journal of the Geological Society of London*, Vol. 84, No. 333, Part 1 (April 30, 1928). 56 pp., 5 figs., 2 pls.

Illing's paper embodies results of the intensive study of an area of about 35 square miles in the southern part of the island of Trinidad, in a district consisting almost wholly of folded and faulted Tertiary clays and marls. The field data were obtained by the examination of structure observed in more than 9,000 pits and about 100 trenches dug for the purpose, and by the study of heavy residues and *Foraminifera* in samples obtained from them. Areal boundaries in obscure places were accurately defined by auger holes, bored to depths of as much as 65 feet in some places.

An accompanying paper by W. L. F. Nuttall ("Tertiary *Foraminifera* from the Naparima Region of Trinidad") describes the *Foraminifera* from 1,270 samples examined, and discusses their value for determining stratigraphic horizons.

Perhaps the best known formation in the area described is that known as the Naparima marl. Of this Illing says that although it has generally been regarded as definitely of deep-water origin, largely because of the presence of radiolarian deposits, yet the field evidence points just as definitely to an opposite conclusion.

> The marl in Naparima is an immense lenticle, tapering rapidly southwards from a maximum of about 1,500 feet to a minimum of 50 feet in a distance of only 2¼ miles. Towards the north, in about the same distance, the marl breaks up into a number of thin beds and interdigitates with the Green Clays, finally disappearing before the boundary of the area is reached. Thus, the one formation with an outstanding lithology, hitherto considered to be the main type in the whole area, is only an impersistent facies, which is not at all consistent in thickness and rapidly disappears in all directions except along the strike.

This statement is believed by the reviewer adequately to explain the conditions that have caused some geologists to believe that there is an upper Green clay and a lower Green clay, respectively above and below the Naparima marl.

Illing also shows that the so-called Alley Creek beds, of thin glauconitic and ferruginous sandstone containing shell fragments and *Foraminifera*, which were erroneously assigned by earlier observers to a horizon below the marl, are within Green clays that overlie the main marl series. The term Green clays is really a lithologic one, representing a facies which in some places is the time equivalent of the marl, but in others is somewhat later. The apparent association of open-water *Foraminifera* with shallow-water conditions and in some places with terrigenous sediments is explained as due to the bringing in of the organic material by marine currents. Other changes in lithology are due to the fact that the area is traversed by an east-west zone of uplift and thrust-faulting, which in earlier times divided it into two partly separated basins of deposition.

In the stratigraphy of Trinidad, an outstanding matter of controversy among geologists who have worked there has been the relative positions of the San Fernando argiline and the Point-a-Pierre grits. Since the work of Wall and Sawkins in 1860 (*Report of the Geology of Trinidad*), and of Cunningham Craig in 1904-1907 (*Council Papers of the Trinidad Government*), the San Fernando formation (argiline) has generally been considered to overlie the Point-a-Pierre (grits); but of recent years some geologists have advanced the opinion that their stratigraphic positions are reversed. The exposures are such that definite determination can not be made from study of the structure, and each is so poor in fossils that such evidence is not conclusive. In 1925 J. A. Bullbrook issued his *Chart Showing Stratigraphy of Trinidad*, in which he placed the Point-a-Pierre as Lutetian ? (middle Eocene) and the San Fernando as Cenomanian ? (Upper Cretaceous). R. A. Liddle, in his recent book on the *Geology of Venezuela and Trinidad*, also gives this relative stratigraphic position for the two formations, based on their lithologic similarity to formations he has studied in Venezuela. He places the Point-a-Pierre as upper to middle Eocene, and the San Fernando as Upper Cretaceous.

In 1926 (*Johns Hopkins Studies in Geology* No. 7) the reviewer assigned the San Fernando (the argiline and overlying Tarouba shales) to the lower

Eocene or possibly Upper Cretaceous, and the Point-a-Pierre (the grits and underlying La Carriere shales) to the Upper and Lower Cretaceous. Illing states that although the argiline has usually been placed in the Cretaceous, he thinks that both it and the overlying Tarouba shales, into which the argiline merges by gradual upward transition, are Eocene, probably upper Eocene, based on foraminiferal evidence. He considers the Point-a-Pierre grits to be probably Cretaceous, as their mineral residue is like that of the shales below, in which limestone lenses carry fossils that have been identified as Lower Cretaceous by Etheridge (1860), Guppy (1873), Sommermeir (1918), G. D. Harris (1922), and R. B. Newton (1924). There has been some discussion as to whether the limestones are *in situ;* but all who have examined these rocks in the eastern part of the island are agreed that the thick, extensive ledges of massive limestone there exposed belong within the shales of the Point-a-Pierre formation.

Nearly all of the formations are separated by unconformities of greater or less amount; and a prominent feature of the structure is the evidence of these breaks in deposition, giving recurrent

conditions of overstep and possible overlap around the main zones of uplift at successive geological periods, so that the formations are not so much a series of superimposed layers evenly spread over the whole area, as a mosaic of lenticles aggregated around certain focal lines. Each lenticle is bounded by planes of disconformity, and

V. C. Illing		*R. A. Liddle*	
Upper Miocene	Poonah series (Moruga series in south)	Upper to Middle Miocene	Moruga formation
Middle Miocene	Naparima clays Unconformity Green clay breccia Erosion base Green clays (includes Alley Creek beds)		
Burdigalian?	Green clays and marls (Naparima marl in south) includes Godineau River marl	Lower Miocene	Naparima formation
Burdigalian Aquitanian	Williamsville clays Amusium beds (St. Croix beds in south) Unconformity		
Oligocene?	Ben Lomond series Unconformity	Lower Oligocene	Alley Creek beds Godineau River marl
Upper Eocene Upper Eocene?	Mt. Moriah formation Unconformity Tarouba shales Argiline (hard argiline) (San Fernando formation)	Upper to Middle Eocene	Point-a-Pierre formation
Lower Cretaceous	Point-a-Pierre formation (sandstones and shales)	Upper Cretaceous	San Fernando formation

each has taken part in the folding and thrusting which occurred after its deposition. It is this mosaic of beds, unconformities, and differential folding which has had to be unravelled in order to obtain a record of the geological history, and it is the interplay of one with the other that has produced so many apparently conflicting data.

Illing's interpretation of the stratigraphy of southern Trinidad is the result of the most intensive study that has been made of that region, and is of great importance also in respect to the geology of the adjacent mainland of eastern Venezuela. As it differs in important points from the stratigraphy as presented by Liddle, the stratigraphic determinations of the two for the Naparima region are here presented for comparison.

The paper as a whole is an excellent example of the intensive study of obscure and complex geologic structure. It should be of especial interest to all who are working on problems of folding and faulting, for it shows what has actually taken place in an area of dominantly soft beds subjected at successive periods to lateral pressure.

G. A. WARING

TULSA, OKLAHOMA
October, 1928

Alluvial Prospecting. By C. RAEBURN and HENRY B. MILNER. Thomas Murby & Company, London, and D. Van Nostrand Company, New York, 1927.

This book, by two British authors, is a sizable volume of 465 pages. Its subject rather hides the fact that it purports to be an exposition of placer prospecting raised to a high plane by the use of the methods of mineral separation and microscopic identification. It amounts to an interesting discussion of placers plus a fairly comprehensive volume on sedimentary petrography.

There are chapters on classification, lithology, prospecting methods, geophysical aids, and on writing a report, which refer strictly to placers. The classification appears to be thorough and is well supplied with examples, many of which are foreign. Lithology simply refers to the kinds of placers on the basis of the valuable mineral. The chapter on prospecting methods consists of 54 pages on the technology of placer prospecting. Geophysical aids receive a brief discussion of only 10 pages. As the last references are of the year 1926, it does not have the advantage of Heiland's recent paper before the American Institute of Mining Engineers, giving results of the application of rather more sensitive and reliable magnetometers. The report chapter is short and concerns the writing of a commercial report on a placer prospect.

The remainder of the book contains material of more diverse interest. Chapter 3, on the "Provenance and Association of Alluvial Minerals," discusses the characteristic minerals of the igneous and metamorphic classes of rocks. It also takes up the varying stabilities of different minerals under weathering conditions. In addition to this valuable material, the chapter gives somewhat less useful data on the mineral associations of cassiterite and platinum placers. Chapter 4 is on the transportation and accumulation of alluvial materials. Here is an opportunity to add something to our neglected philosophy of sedimentary deposition, although in this case it is applicable

only to shoestring sands of the river-channel type. Chapter 7 is a chapter on mineralogy without the microscope under the title of "Field Examination of Alluvial Concentrates."

Chapters 9 and 10 carry the title, "The Laboratory Investigation of Alluvial Minerals." They include pages 227 to 450. They really amount to a book on sedimentary petrography. There is discussed the separation or isolation of specific minerals or groups of minerals by various means. Hand sorting, heavy liquid, magnetic, dielectric, and vibration methods are described. The next part is on the examination and determination of sedimentary minerals. Micro-chemical tests and reactions and the various optical determinations with the petrographic microscope are included. Finally, there are full descriptions of the different alluvial minerals and their properties, accompanied by wonderful pictures. It is unfortunate that the minerals actually found so seldom resemble their photographs.

Altogether the book looks like a useful volume from the standpoint of oil geologists.

RANSOM E. SOMERS

THE GULF COMPANIES
PITTSBURGH, PENNSYLVANIA
October, 1928

"A Magnetic Resurvey of Part of the Northamptonshire Iron Field." By W. A. FORDHAM. *The Mining Magazine* (London), July, 1928, pp. 18-25.

The article gives a description of the new vertical magnetometer made by L. Oertling, Ltd., of London, and the results of its application in the resurvey over a bed of ironstone in Northamptonshire. The instrument is a new, sensitive design of the old Thompson-Thalen magnetometer and consists of two thin horizontal bar magnets balanced on an agate knife edge. Instead of measuring the angular deflection of the balance, the deflection is counterbalanced by the vertical movement of two vertical magnets placed below the balance and the latter is brought back to the horizontal. The relative intensity of the vertical component of magnetism, compared with the base station at which the balance has been adjusted to the horizontal, can then be calculated (in the field read from prepared tables) from the change in position of each of the vertical magnets. The balance is compensated for temperature changes; the one used by Fordham had a temperature correction of 0.3° per 1° F. The time necessary for a single station or the number of stations possible per day is not given, but Table II seems to indicate that Fordham took 32 stations in one day; 9 stations on one mile of traverse and 23 stations on 1½ miles of traverse.

The resurvey in Northamptonshire consisted of 32 stations in a broken traverse across the ends of a bed of ferrous carbonate near Irthlingborough. Absolute magnetic measurements had been made at five stations in that general neighborhood some years before. The results of the variometer measurements do not altogether agree with the absolute measurements, are fairly con-

sistent among themselves, seem to indicate the presence of the iron ore bed, but are not extensive enough to warrant much interpretation.

DONALD C. BARTON

HOUSTON, TEXAS
October, 1928

"Notes on the Determination of Alkalies and Their Separation from Sesquioxides." By K. L. MALJAROFF. *Transactions of the State Petroleum Research Institute*, Moscow, U. S. S. R., 1927. 38 pp. In Russian with a summary in English.

Methods are given: (1) two methods of quick determination of alkalies in well waters according to the reaction $NaCl \rightarrow Na_2Cl_2O_4 \rightarrow Na_2CO_3$ by the use of oxalic acid; (2) determination of sesquioxides by means of hydrazine hydrate; (3) determination of sesquioxides by means of oxalic acid; (4) separation of the alkalies from the sesquioxides by means of oxalic acid.

"Notes on Methods of the Determination of Pore Space in Rock." By V. A. SILBERMINZ and V. N. KRESTOVNIKOV. *Transactions of State Petroleum Research Inst.*, U. S. S. R., 1928. 41 pp. In Russian with a summary in English.

The writers compared Skobeltzin's method of water absorption in vacuum of rock samples previously saturated with ammonia, the method of simple water absorption in vacuum, and Melcher's method. The peculiar points of Skobeltzin's method were found to be superfluous. The simple water absorption in vacuum method and Melcher's were found to lead to similar results. The former method is the more advantageous for numerous determinations of sufficiently hard rocks; the latter is the more advantageous for single determinations with soft rocks.

DONALD C. BARTON

HOUSTON, TEXAS
October, 1928

ABSTRACT

"La coupe geologique le long du chemin de Mucuchachi a Santa Barbara dans les Andes venezueliennes." (The geologic section along the road from Mucuchachi to Santa Barbara in the Venezuelan Andes.) By PETER CHRIST. *Ecologae Geologicae Helvetiae*, August, 1927.

The town of Mucuchachi is in the southern part of the state of Merida, in the Venezuelan Andes. From Mucuchachi, a famous old trail leads southeast down the mountains to Santa Barbara, at the edge of the Llanos plain in the southwest part of the state of Zamora. It is along this trail that Mr. Christ made detailed observations of the geologic section.

STRATIGRAPHY

The oldest beds, known as the *Mucuchachi series*, are exposed in the valley of Mucuchachi River in the Venezuelan Andes. These beds, which are black

argillaceous schists, in places calcareous or siliceous, are Archean in age and form the basement complex in this region. Just south of Mucuchachi, these beds are sharply upturned and in places the structure is complex.

The Caparro-Bellavista series lies unconformably on the Mucuchachi beds. It consists mainly of schists ranging from sandy and mica schists to argillaceous, quartzite schists. This series is Lower Paleozoic and has a thickness of approximately 3,000 meters.

The Mucupati series lies unconformably upon the Mucuchachi series and the Caparro-Bellavista series. The unconformity between the Mucupati series and the Mucuchachi is very marked. The Mucupati beds are Devonian in age and are composed of sandy clays, sandstones, and conglomerates, with some quartzites and, at the base, some porous limestone beds. The thickness of the Mucupati is about 1,200 meters.

The Palmarito series of Carboniferous age lies on the Mucupati series. In places, it is plainly unconformable; in others it is seemingly conformable. These beds are about 300 meters thick, and are made up of sandy clays containing many fossils. It appears to be the most fossiliferous horizon in the entire section.

Unconformably above the Palmarito series lies the *Lomita series*. Red conglomerate, sands, and red sandy clays make up this formation. It is considered of Lower Cretaceous age, with the basal part possibly belonging to the Permian. In places the Lomita beds overlap the Mucuchachi series throughout long distances and with strong unconformity.

The Santa Barbara series, of Middle Tertiary age, consists mainly of shales and clays. An unconformity of tectonic origin separates them from the Lomita series. The Santa Barbara series, together with more recent sediments of Quaternary age, makes up the Llanos plain, which extends far toward the south and east. The Santa Barbara beds are the youngest observed in this section.

Although this discussion presents the general stratigraphic section, there are many local differences where strong unconformities exist.

From Mucuchachi down the trail to Legunita, the Mucuchachi basement is covered by the Lomita beds, the intervening sediments having been eroded. Farther down the mountains at Alto de Arenal, the Mucuchachi beds disappear under the Palmarito, which replace the Lomita beds at the surface. These Palmarito beds contain fossils identified as *Fenestella*, *Productus*, gastropods, brachiopods, and others. Small trilobites and small bivalves were also found. These fossils established the age of these beds as Carboniferous. Near La Aguada, the Palmarito series is replaced by the Mucupati beds, which are exposed at the south as far as Santa Cruz. From Santa Cruz to Boca del Monte are the Caparro-Bellavista beds. The Santa Barbara series is next exposed, being separated from the Caparro-Bellavista series by a sharp fault caused by the tectonic intrusion prior to the deposition of the Santa Barbara beds.

TECTONICS

The relation of the different beds is irregular. These conditions cannot be explained by a single cycle of orogenic movements, since they are the result of a long and complicated tectonic history.

Pre-Cambrian cycle.—During this period, the schists (Mucuchachi), with locally interbedded sandstones, were deposited, but deposition was interrupted

several times by periods of intense folding. Evidence of this history is shown to-day by the strongly uplifted and folded beds of the Mucuchachi series.

Pre-Caledonian transgression.—The first cycle of folding was followed by peneplanation, and that, in turn, by the first Paleozoic transgression. The Caparro-Bellavista series was then deposited. Toward the end of the Lower Paleozoic, a second cycle of folding occurred which may be termed the Caledonian period of folding. This period should have built fairly high mountains. Erosion followed, bringing about peneplanation.

Post-Caledonian transgression.—Toward the end of this period, the sea encroached toward the north. It did not necessarily extend to the north of the present Venezuelan Andes, but it seems that at least an arm crossed Tachira as far as the Maracaibo basin. The sediments deposited are the Mucupati series. Following this deposition, there was slight uplift in certain parts of this series and also slight erosion occurred where islands had emerged.

Pre-Hercynian transgression.—A shallow sea encroached and deposited the Palmarito series, rich in fossils, above the Mucupati series, with some depositional irregularities. These beds are Carboniferous in age.

Hercynian folding.—This was a period of very intense folding, creating great mountains and uplifting a vast region. Then followed a continental period of comparatively long duration in which there was no great movement.

Post-Hercynian transgression.—This movement probably started from the south. The Lower Cretaceous and perhaps even Permian beds were laid down over the region northwest of the present Venezuelan Andes. During the deposition of the Lomita series, there were probably periods of strong uplift, of gentle folding, and periods of rest. Such a history explains the marked variations in the sedimentation of the Lomita series.

Alpine cycle.—This folding probably began in late Cenozoic time, forming the present Venezuelan Andes. During the period, a fairly complete Tertiary section was deposited, both north and south of the mountains. Probably a little after the last great uplifting, a depression occurred south of the present Venezuelan Andes. A mountain range separated itself sharply from the Llanos by a flexure which, in the course of intense sinking on the south, formed a veritable Andean bordering fault which separates to-day the massif of the mountains from the basin of the Llanos. This flexure passes just west of Boca del Monte. The Llanos beds are not depositional beds, since there was no later transgression in present Venezuela, following the Alpine cycle. Instead, these Llanos beds are the product of erosion from the main massif and were carried down from the mountains to the plains by a great number of streams, rivers, and torrents.

It is likely that the southeast flank of the Andes was again upraised in Pleistocene time and at several later periods. Later Alpine movements caused fairly strong inclinations toward the southeast, supplemented by a sinking toward the southeast which should have caused these strong inclinations and the deposition of a new series in the valleys and lower parts of the plain. The whole region was raised again, but the same general structural lines now exist.

C. C. ZIMMERMAN[1]

PITTSBURGH, PENNSYLVANIA
September 27, 1928

[1]Introduced by K. C. Heald.

RECENT PUBLICATIONS

GENERAL

"Bentonite in Correlation," by Frederick W. Sardeson. *The Pan-American Geologist*, Vol. 50, No. 2, pp. 107-16.

"Magnetic Tables and Magnetic Charts for 1925," *U. S. Coast and Geodetic Survey*, Washington, D. C., 1929. Now ready in photostat form at cost of photostats.

"Topographic Instructions of the United States Geological Survey," by C. H. Birdseye. *U. S. Geological Survey Bulletin 788*. Superintendent of Documents, Washington, D. C., 1928. v+432 pp., 29 plates, 18 figs. Price, $0.60.

CALIFORNIA

"How California Has Conserved Oil," by J. E. Eaton. *Oil Bulletin* (Los Angeles), October, 1928, pp. 1030-37, 2 figs.

"The Rincon Oil Field," by O. F. Kotick. *Oil Bulletin*, October, 1928, pp. 1033-37, 7 figs.

CANADA

"Developments of Petroleum and Natural Gas in Canada," by G. S. Hume. *Journal Institution Petroleum Technologists* (London), August, 1928, pp. 669-76.

GEOPHYSICAL PROSPECTING

The American Institute of Mining and Metallurgical Engineers, New York, has recently issued the following technical publications:

"Discussion of the Papers on Geophysical Prospecting Presented at the New York Meeting, February, 1928." *No. 130.*

"Operating Principles of the Inductive Geophysical Processes," by J. J. Jakosky. *No. 134.*

"Modern Instruments and Methods of Seismic Prospecting," by C. A. Heiland. *No. 149.*

"A Background for the Application of Geomagnetics to Exploration," by Noel H. Stearn. *No. 150.*

"The Dip Needle as a Geological Instrument," by Noel H. Stearn. *No. 151.*

GERMANY

Petroleum Zeitschrift (Berlin-Vienna) for September, 1928, contains among other articles the following:

"Salzstöcke und Erdöllagerstätten" (Salt Domes and Petroleum Deposits), by A. Bentz;

"Tiefbohrung auf Ölschiefer und Steinkohlen in Rotliegendbecken von Saalhausen bei Oschatz in Sachsen" (Deep Drilling in Oil Shale and Coal in the Rotliegend Basin of Saalhausen at Oschatz, Saxony), by K. München.

"Bituminöse Schiefer und ihre Besiehung zum Erdöl" (Bituminous Shale and its Relation to Petroleum), by A. F. v. Stahl.

ISOSTASY

The following list of papers that have been published by the U. S. Coast and Geodetic Survey is given for the use of geophysicists and others interested in isostasy and related subjects. Orders should be sent to the Superintendent of Documents, Government Printing Office, Washington, D. C.

"The Figure of the Earth and Isostasy from Measurements in the United States." Price, $1.35.

"Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy." Price, $0.85.

"The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity." Price, $0.35.

"Determination of Time, Longitude, Latitude, and Azimuth." Price, $0.35.

"Fourth General Adjustment of the Precise Level Net in the United States and Resulting Standard Elevations." Price, $0.40.

"Investigations of Gravity and Isostasy." Price, $0.40.

"A Study of Map Projections in General." Price, $0.05.

"Elements of Map Projection." Price, $0.50.

"Modern Methods for Measuring the Intensity of Gravity." Price, $0.15.

"Isostatic Investigations and Data for Gravity Stations in the United States Established since 1915." Price, $0.25.

"Geodetic Operations in the United States, January 1, 1924, to December 31, 1926." Price, $0.20.

MISSISSIPPI

"Ripley Greensands of Mississippi," by C. E. Needham. *The Pan-American Geologist*, Vol. 50, No. 2 (September, 1928), pp. 117-20.

OKLAHOMA

The Oklahoma Geological Survey has issued new publications as follows:

"Oil and Gas Geology of Muskogee County, Oklahoma," by Hale B. Soyster and Thos. G. Taylor. *Bulletin 40-FF*, September, 1928. 28 pp., 3 figs., 4 plates. Price, $0.30.

"Geology of Logan County," by Hubert E. Bale. *Bulletin 40-GG*, September. 18 pp., 2 figs., 2 plates. Price, $0.30.

"Oil and Gas in Oklahoma." *Bulletin 40*, Vol. 1, August. Contains separates B, D, G, J, P, Q, and AA. 287 pp., 4 figs., 7 plates. Cloth. Price, $1.65.

"Oil and Gas Geology of Carter County," by C. W. Tomlinson. *Bulletin 40-Z*. Norman, Oklahoma, September, 1928. 78 pp., 15 figs., 3 plates. Price, $0.30.

PRODUCTION METHODS

The American Institute of Mining and Metallurgical Engineers, New York, has recently issued the following technical publications:

"Capillary Phenomena as Related to Oil Production," by Frederick G. Tickell. *No. 138*.

"Deep Well Pumping in California," by Hallan N. Marsh. *No. 143*.

"Oil Recovery Investigations of the Petroleum Experiment Station of the U. S. Bureau of Mines," by R. Van A. Mills, Joseph Chalmers, and J. S. Desmond. *No. 144.*

"Rotary Drilling Problems," by R. S. Cartwright. *No. 145.*

"Intermittent Injection of Gas in Gas-Lift Installations," by Morgan Walker. *No. 146.*

"Relative Propulsive Efficiencies of Air and Natural Gas in Pressure Drive Operations," by Harry H. Power. *No. 148.*

TEXAS

"Magnetic Declination in Texas in 1927," *U. S. Coast and Geodetic Survey*, 1928. Superintendent of Documents, Government Printing Office, Washington, D. C. Price, $0.15.

WEST VIRGINIA

"Detailed Report of Pendleton County," by John L. Tilton and Wm. F. Prouty, assisted by Paul H. Price and R. C. Tucker. *West Virginia Geological Survey*, Morgantown, West Virginia, 1927. xx+358 pp., 80 halftones, 25 text figs., and case of maps. Price, $2.50.

THE ASSOCIATION LIBRARY

Headquarters acknowledges library accessions:

AUSTRALIA

From E. de Hautpick:

Are There Oil Prospects in Australia?

CANADA

From William Bowie:

"Gravity in Western Canada"

COLORADO

From J. Harlan Johnson:

"A New Locality for Fox Hills Fossils in Colorado"

"New Cretaceous Mollusks from Colorado and Utah," by John B. Reeside, Jr.

GENERAL

From William Bowie:

"Causes and Prediction of Earthquakes"

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

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PRELIMINARY ANNOUNCEMENT OF PROGRAM FOURTEENTH ANNUAL MEETING, FORT WORTH, TEXAS, MARCH 21, 22, 23, 1929

A tentative program of the fourteenth annual meeting of the Association is announced herewith. General chairman, J. Elmer Thomas, 602 Fort Worth Club Building, and B. E. Thompson, president of the Fort Worth Geological Society, have indicated the general scheme and the several special committees are already working on the details of their plans. The September *Bulletin* contains the list and personnel of the several committees.

The Texas Hotel is to be convention headquarters. In accordance with the wishes of the executive committee, the local committee will avoid extravagance in entertainment features, but members may expect something typical of Texas in the way of hospitality. Special field trips may be arranged by request.

R. A. Liddle, chairman of the program committee, has arranged a tentative program of the technical sessions. The principal theme of the meeting is to be a symposium on the stratigraphy of the Permian Basin of the southwestern United States under the leadership of Alex W. McCoy. Chairman McCoy is soliciting the papers for this symposium as well as prepared discussions. Both the papers and the discussions will be available in mimeographed form at the meeting for the convenience of those who may participate in the oral discussion. Other special subjects for which papers may be submitted are shown in the program. Two outstanding groups include papers on crooked holes and on applied geophysics.

Though the tentative program as printed herewith appears to provide no time for general and miscellaneous papers, attention is here particularly called

to the fact that papers on any subjects which members may wish to present are earnestly solicited. Provision will be made for the presentation of papers not naturally falling into the special program in group sessions which will be so arranged by topics as to conflict as little as possible with other sessions.

Members intending to submit papers for this meeting, either on the subjects listed, or on other subjects, should communicate with R. A. Liddle, Box 1007, Fort Worth, Texas, as soon as possible in order that detailed plans for the program may be completed. Manuscript should, if possible, be submitted early in January.

THURSDAY MORNING, MARCH 21, 11-12 NOON

1. Revision of Formation Contacts and Mapping of the Pennsylvanian in North-Central Texas
2. Crooked Holes in Oil-field Development
3. Recent Exploration for Oil in Michigan

THURSDAY AFTERNOON, MARCH 21, 2-5:00
STRATIGRAPHY

Symposium on the Stratigraphy of the Permian Basin of Southwestern United States

Chairman: Alex W. McCoy

General Papers: Correlation of the Pennsylvanian and Permian of the Delaware and Glass Mountains with the Pannsylvanian and Permian of the Great Salt Basin of Western Texas and Eastern New Mexico

Discussion (written and oral)

FRIDAY MORNING, MARCH 22, 9:30-12 NOON
STRATIGRAPHY

Symposium on the Stratigraphy of the Permian Basin of the Southwestern Part of the United States

Chairman: Alex W. McCoy

General Papers: Correlation of the Permian of Texas and Eastern New Mexico with the Permian of Oklahoma, Kansas, Wyoming and Utah

Discussion (written and oral)

FRIDAY AFTERNOON, MARCH 22, 2-5:00
APPLIED GEOPHYSICS AND FOREIGN PAPERS

1. Geological Interpretation of Geophysical Data and Operations
   Discussion (written and oral)
2. Influence of Oil from Mesopotamia and Persia on the Petroleum Market of the United States
   Discussion (written and oral)
3. Influence of Venezuelan Production on the Oil Market of the United States
   Discussion (written and oral)

SATURDAY MORNING, MARCH 23, 9:30-12 NOON
STRUCTURAL GEOLOGY

1. Resumé of Developments in West Texas
2. Tectonics of West Texas and Eastern New Mexico
   Discussion (written and oral)
3. Resumé of Development in East Texas
4. Tectonics of East Texas
   Discussion (written and oral)
5. The Greensands of East Texas
   Discussion (written and oral)

SATURDAY AFTERNOON, MARCH 23, 2-5:00

1. New Discoveries in the Upper Cretaceous of the Atlantic and Gulf Coastal Plains
2. Stratigraphic Information Obtained from Drilling into the Lower Cretaceous in Southern Arkansas and Northern Louisiana
   Discussion (written and oral)
3. General paper on California
4. General paper on Seminole, Oklahoma

The annual meeting of the Society of Economic Paleontologists and Mineralogists will be held in conjunction with the meeting of the American Association of Petroleum Geologists

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OFFICIAL REGIONAL VISITS

President R. S. McFarland and business manager J. P. D. Hull visited Association districts in the south Mid-Continent region during the first week of October. Through coöperation with the several district representatives of the A. A. P. G. and the local geological societies, special meetings were arranged at which members and officers had the pleasure of becoming better acquainted. The districts visited were Amarillo, Wichita Falls, Fort Worth, Dallas, Shreveport, and Houston. Although this itinerary could not be arranged on the regular meeting days of all the societies visited, a pleasingly large number of geologists attended the luncheons and evening meetings. Altogether, more than 200 members and prospective members of the A. A. P. G. were thus able to learn of the activities of the Association, particularly the work being done at headquarters at Tulsa. The enthusiasm shown by the local groups in this Texas-Louisiana trip as well as in the official visits which the president and other officers have made previously in Oklahoma, Kansas, and Colorado is very gratifying to the executive committee and indicates the desirability of continuing each year this policy of visiting local groups and holding informal round-table discussions on Association affairs. After this trip to the Gulf Coast, President McFarland planned to attend the annual meeting of the Pacific Section at Los Angeles, California.

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

The Society of Economic Geologists will hold its annual meeting with the Geological Society of America in New York on December 27, 28, and 29.

WALDEMAR LINDGREN, chairman of the committee on bibliography of economic geology of the National Research Council, has announced that $18,000.00, the amount desired, has been pledged for the establishment of an Annotated Bibliography of the International Literature of Economic Geology. The price will not exceed $5.00 per year. The bibliography covering 1928 will appear in a single volume of about 400 pages, which will probably be ready for distribution about June 1, 1929. Orders should be sent to Economic Geology, Urbana, Illinois, U. S. A.

LEWIS B. KELLUM has resigned as geologist for Compañia Transcontinental de Petroleo of Tampico, Mexico, to become an associate in the geological department of the University of Michigan.

J. M. MCMILLAN, JR., who has been in the geological department of the Empire Oil and Refining Company for three years, has accepted a position on the geological staff of the Skelly Oil Company at El Dorado, Kansas.

WILBUR A. NELSON resigned as state geologist of Virginia on September 1, 1928. For the past three years, Mr. Nelson has held the joint position of state geologist and head of the School of Geology at the University of Virginia. Beginning September 1, these two positions have been separated and Mr. Nelson will devote his entire time to his official duties at the University of Virginia.

LINWOOD H. WARWICK, chief clerk of the survey since its organization, has been appointed acting head of the Virginia Geological Survey, whose offices will be at the University of Virginia as heretofore.

G. C. SIVERSON, formerly of the geological department of The Pure Oil Company, is now with the Tidal Oil Company at Tulsa, Oklahoma.

LEROY G. WELSH, formerly chief geologist for the New England Oil and Pipeline Company at Tulsa, Oklahoma, has opened a consulting office at Abilene, Texas.

CHARLES T. KIRK, consulting geologist of Tulsa, Oklahoma, is chief geologist for the Peters Petroleum Corporation of Tulsa.

J. A. ROSS has joined the geological staff of the Peters Petroleum Corporation of Tulsa.

WALT M. SMALL, of Cooperstown, Pennsylvania, may be addressed as follows: Cia. de Petroleo de Angola, Caixa Postal 315, Loanda, Angola, P. West Africa.

FREDERICK G. CLAPP, having left Persia, has located his family in France for the winter. He can be reached by his friends at No. 68 Quai d'Auteuil, Paris XVI, or at his usual Church Street address in New York City.

C. J. HARES is the author of "Geology and Lignite Resources of the Marmarth Field, Southwestern North Dakota," U. S. Geological Survey Bulletin 775.

U. R. LAWES, of the Roxana Petroleum Corporation, has moved from El Reno, Oklahoma, to Garden City, Kansas.

J. W. BEEDE, for several years with the Dixie Oil Company at San Angelo, Texas, is now on the geological faculty of Indiana University at Bloomington, Indiana.

Mr. and Mrs. HANS E. THALMANN announce the birth of a daughter, Marianne Ursula, at Berne, Switzerland, August 15, 1928. Mr. Thalmann and his family have returned from Europe and may now be addressed in care of La Corona SA, Apartado 238, Tampico, Tamps., Mexico.

Mrs. LAURA LEE WEINZIERL, *nee* Laura Lee Lane, died very suddenly in Houston, Texas, September 28, 1928. Mrs. Weinzierl was engaged as consulting micro-paleontologist, being associated with ALEXANDER DEUSSEN, consulting geologist of Houston. She graduated from the University of Texas, in 1923, and entered the employ of Mr. Duessen in that year. Later she became a member of the geological staff of the Marland Oil Company of Texas, when this company was operating in the Gulf Coast district of Texas in the years 1925 and 1926. She married JOHN F. WEINZIERL, April 3, 1926. Mrs. Weinzierl had been engaged in the consulting business since the first of January, 1928.

R. W. HARRIS is instructing in micro-paleontology at the University of Oklahoma at Norman, after two years of work with JOSEPH A. CUSHMAN at Sharon, Massachusetts.

GEORGE H. ASHLEY is the author of "Bituminous Coal Fields of Pennsylvania," Bulletin M 6, Part 1, of the State Geological Survey.

J. ELMER THOMAS, petroleum analyst with Fenner & Beane at Fort Worth, Texas, had an article on "New Economics in Oil Production" in the *Oil & Gas Journal* of October 25, 1928.

L. SPARGEN has written several articles on magnetometer methods and surveys which have appeared in the October numbers of the *Oil & Gas Journal*.

K. C. HEALD, of The Gulf Companies, Pittsburgh, Pennsylvania, addressed the local and visiting geologists at the smoker given by the Tulsa Geological Society, October 23, in connection with the Fifth International Petroleum Ex-

position at Tulsa, Oklahoma. Dr. Heald's subject was "Some Unsolved Fundamental Problems of the Petroleum Geologist."

GEORGE OTIS SMITH, director of the U. S. Geological Survey and president of the A. I. M. E., was the principal speaker at the smoker of the petroleum division of the A. I. M. E. at Tulsa, October 18. His topic was "The Continued Need for an Open Forum."

HARRY H. HILL has resigned his position as chief petroleum engineer of the U. S. Bureau of Mines to accept a position with the Standard Oil Company of New Jersey.

E. B. HUTSON, paleontologist with the Standard Oil Company of Louisiana at Shreveport, was married on October 13, to Miss Aileen Poe of Lufkin, Texas.

H. K. SHEARER, who has been geologist with the Standard Oil Company of Louisiana at Shreveport for several years, was married on October 21, to Miss Gussie Louise Woods at Lake Village, Arkansas.

J. B. TEMPLETON, formerly chief geologist for the Sun Ray Oil Company, 402 Mid-Continent Building, Tulsa, sailed for Venezuela on November 1 to do geological work for Brokaw, Dixon, Garner & McKee. He will be gone four months. His home address is 515 North 17th Street, Muskogee, Oklahoma.

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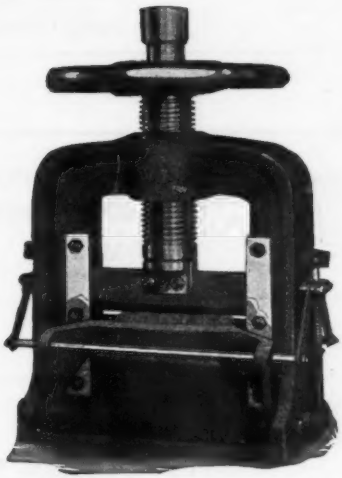

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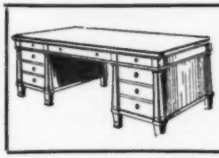

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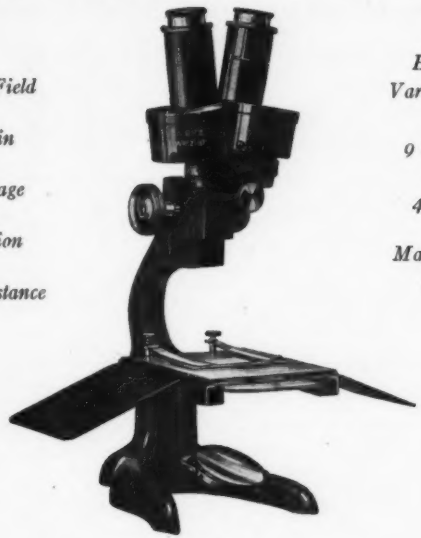

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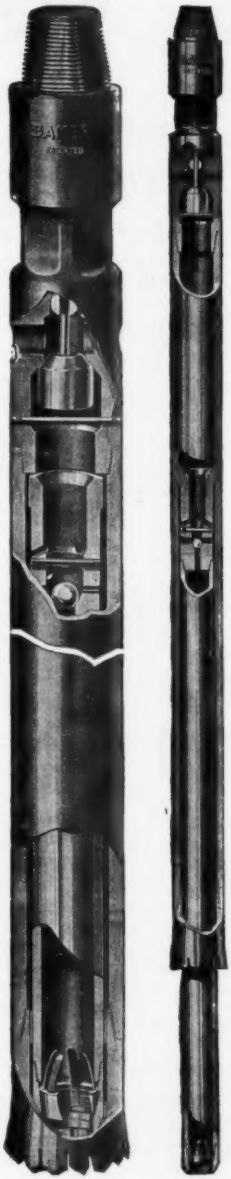

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